IMPERIAL DEPARTMENT OF AGRICULTURE FOR THE WEST INDIES.

LECTURES TO SUGAR PLANTERS.

ISSUED BY THE COMMISSIONER 1906

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LECTURES

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SUGAR PLANTERS.

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PREFACE.

The Lectures to Planters, of which a summary is contained in the following pages, were delivered by the Officers of the Imperial Department of Agriculture at Barbados about three years ago. They were fully reported at the time in the local newspapers, and served a useful purpose in drawing attention to the best means for improving the field treatment of the sugar-cane and the use of artificial and pen manures, while at the same time ensuring a reduction in the cost of production per ton of canes. This is generally admitted is higher at Barbados than in any other sugar-producing area in the West Indies.

As the time will probably arrive when still greater attention will require to be devoted in the directions above referred to it has been suggested, with the view of emphasizing the advice and information already given, that the Lectures might be published in a collected form, in order to be conveniently at hand for the purpose of reference.

During the period that has elapsed since the lectures were delivered there is evidence that there has been a perceptible improvement in agricultural methods. A deeper interest has also been taken in the selection and use of manures, with the result that the money spent, especially on artificial manures,

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LECTURES TO PLANTERS.

LECTURE I.

THE NATURAL HISTORY OF THE SUGAR-CANE.

SIR DANIEL MORRIS, K.C.M.G., M.A., D.C.L., D.Sc., F.L.S.,

Imperial Commissioner of Agriculture for the West Indies.

It is with pleasure that I open this first course of lectures with a view of assisting the efforts to improve the cultivation of the sugar-cane, and so contribute to the welfare of an island, which is so largely dependent on the sugar industry.

The lectures will, it is hoped, appeal not only to the planters in Barbados but to those in other colonies where the circumstances of the industry are of a somewhat similar character. It is proposed that the information be plainly worded and exactly suited to the requirements of these colonies, in order that it may stimulate amongst the planting community a desire for further information found in the leading text-books on the subject.

The first lecture will deal with the life-history of the sugar-cane, that is, it will contain a description of the plant in its several stages of growth, and explain the part played by each of its various organs in building up the structure which enables it to produce economically the particular product for which it is grown, viz., cane sugar. In later lectures information will be supplied in regard to the character and composition of the soil, the use of manures, the best methods of cultivation and the treatment of the various diseases—insect and fungoid—by which the sugar-cane is liable to be attacked.

Although primarily intended for the younger members of the planting community, who have expressed a desire to have explained to them some of the scientific facts on which is based the agricultural practice in which they are daily engaged, it is hoped that these lectures will be of interest to all who are interested in the sugar industry.

Our object is to extend a sound knowledge of the principles of agriculture amongst the members of the planting community. It has been shown, for example, that a scientific knowledge of plant life enables the cultivator to adopt in cases of emergency expedients that otherwise he would be unable to do. It tends to sharpen his wits and to train his mind to habits of correct observation, it leads him to reason from cause to effect and to surmount difficulties which to a man equipped with practical knowledge only would appear insurmountable.

The planter to be successful must, of course, be intimately acquainted with all the practical details of his work. There is no choice for him in this matter. I would go so far as to state that a man who does not possess a sound knowledge of such details, that is, who is not a practical planter, cannot be successful, although he may have already acquired a considerable knowledge of science. His science alone will be useless to him. The class of planter we require in these days is one that has made a discriminating use of the teaching of science based on observation and the results of careful experiment. The planter should be practical first and scientific afterwards, and, when we have scientific knowledge engrafted upon practical experience, we have the combination which is most desirable and which would enable him to hold his own even in periods of great depression. It is fully recognised that in these days we must keep abreast of the progress continually taking place in agricultural matters or we shall be left behind and our industry will suffer.

The motto of the Imperial Department of Agriculture is "Education and Research." As you are aware, all the members of the Department are earnestly desirous of assisting and advising the planters in these colonies in scientific matters, and thus afford them the means for maintaining the staple industries in such a condition as to successfully compete with other countries. This can only be accomplished by a sound agricultural education leading to

the adoption of the best methods for dealing with crops and by reliable experiments based on thorough and exhaustive research.

The field treatment of the sugar-cane at Barbados has received very careful attention, and by means of an abundant supply of labour it has been possible to maintain it at a high standard. It would, however, be unwise to rely too much on this one fact. A more economical use of labour and a more intelligent selection and application of manures, as well as a more skilful treatment of cane diseases (capable of being successfully dealt with at a small cost and thereby saving the loss of thousands of tons of sugar per annum) are matters that would immediately repay the attention of the planting community.

These lectures, it is hoped, will also be regarded as having a direct bearing on the welfare of all classes of the community, for all depend on agriculture. It is evident we have arrived at a stage in the industrial history of these islands when it is imperative to enlist the interest and co-operation of the most intelligent and enterprising people in them in order to adopt, in the cultivation of the soil, the handling of manures and the preparation of agricultural produce, the most skilful and economical methods that may be found applicable to our circumstances, and to keep in touch with the modern teachings of science.

THE SUGAR-CANE.

Historical.

The sugar-cane is now cultivated in all the warm parts of the world on both sides of the equator, ranging from New Zealand, 37 degrees South, to Southern Spain, 37 degrees North.

The native home of the sugar-cane is still a matter of doubt, but evidence, on the whole, seems to point to India or some of the islands of the Pacific as being the region from which it was originally obtained. From this it has spread, or been carried, to China and Arabia. Afterwards it was introduced by the Arabs to Sicily and Southern Spain, where it is still cultivated to a moderate extent.

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but the real joint of the sugar-cane is the node. If we divide the ripe stem, longitudinally, we shall see at a glance that the node extends transversely right through the cane, and forms a tangled plate of fibres (Fig. 6). The internodes, on the other hand, are composed of soft tissue with numerous straight fibres running up and down.

Returning to the outside of the cane, immediately below each node occurs a narrow whitish band composed of a white powder made of rods of wax. Above this comes the scar of the fallen leaf, then comes the bud, and on the same level as the bud is to be seen another band, encircling the whole stem, which consists of rows of semi-transparent dots, showing the position of the "sleeping roots." These arise from the inside of the stem, and, when the cane is exposed to excessive moisture or when the node is planted in moist soil, they force their way through the outer tissues and are ready to perform the duties of a root system.

From the above it will be observed how admirably the sugar-cane is adapted for being grown from joints. A bud may be seen under the base of each leaf arranged on alternate sides of the stem. These buds are usually called the "eyes" of the cane, and each one is capable, given the proper conditions, of growing into a branch like the parent stem.

The leaves of the cane are also alternate, and, like those of other grasses, consist of a *blade* and a *sheath* which envelops the stem. These sheaths are split and they are sometimes covered with stinging hairs. The long, flattish, green blade spreads outwards three to four feet long, and it has a whitish, purplish or reddish mid-rib.

The leaves are the factory in which the plant, under the influence of sunlight, elaborates its food and assists not only to build up the plant, but to prepare the sugar and albuminoids in its cells.

In many of the varieties of sugar-cane the stem occasionally elongates and bears flowers. The whole flowering mass produced at the end of the hollow elongation of the stem, is known as the *inflorescence* or "arrow." The inflorescence is repeatedly branched and the small branches bear laterally a number of flowers or *spikelets*. Each spikelet contains a single flower, and from the base of each spikelet spring a large number of delicate, stiff, white hairs, which give the arrow its glistening fluffy appearance.

ANATOMY AND PHYSIOLOGY OF THE SUGAR-CANE.

The sugar-cane, like all other flowering plants, is made up of the "*root*" that grows downwards into the soil for the purpose of absorbing food substances and of anchoring the plant, and the "*shoot*" that grows above the ground and consists of the stem, on which the leaves are borne laterally, and which is prolonged, occasionally, into the inflorescence.

The Root System.

The root system of the sugar-cane is fibrous, consisting of a large number of thin, independent roots arising from the stem. They seldom or ever branch and are usually short lived, their places being taken by a constant development of new roots from underground portions of the stem.

If we take a cutting from the top of a sugar-cane and place it in deep soil, the buds upon it will begin to swell, and the sleeping roots, just above the node, will start into growth. (Fig. 1.)

FIG. 1.

Cutting from top of a sugar-cane, showing bud pushing through the base of the leaf-sheath and the sleeping roots beginning to develop.

As the buds develop and appear above the ground the roots elongate rapidly downwards. While the soil is moist the roots remain near the surface, but when the surface soil becomes dry they strike deeper for moisture and food.

A large root development is essential to the success of the sugar-cane, hence the necessity for the careful cultivation of the soil, so that the roots can permeate every part of it and obtain suitable food material.

From the base of the first and usually strongest shoot, which is called the "mother" cane, spring up secondary shoots, and so there is gradually formed a "stool" of canes consisting of a mass of underground stems (called the *root-stock*) and *roots*, with a "clump" of upright stems each surmounted by its mass of leaves.

The youngest portion of the root is always nearest the tip, for growth takes place at the root-tips only, and it is by lengthening out in this manner that the root slowly forces its way through the particles of soil. The most vital portion of a root is, therefore, its tip, and in order to protect this there is a covering over it, called the *root-cap*. This undergoes continued renewal from inside as its outer layers get worn away through the forcing of the root between particles of soil.

If a cane cutting were placed for observation in water or in a moist chamber, we would notice that, at a point a little behind the tips of the young string-like roots, a large number of fine, delicate whitish hairs spring from the root itself. These are the *root-hairs*, and it is through these root-hairs chiefly that the plant draws its nourishment from the soil.

Anatomy of the Root System.

If we cut a thin section of the root of the sugar-cane in that part n which the root-hairs occur, and examine it under a microscope, e see that the root is built up of a number of closely-packed cells. We also notice that the cells of the root are divided into two parts the centre of the root being occupied by cells of varied sizes

and shapes, and the outer part composed of thin-walled cells more or less alike. (Fig. 2.)

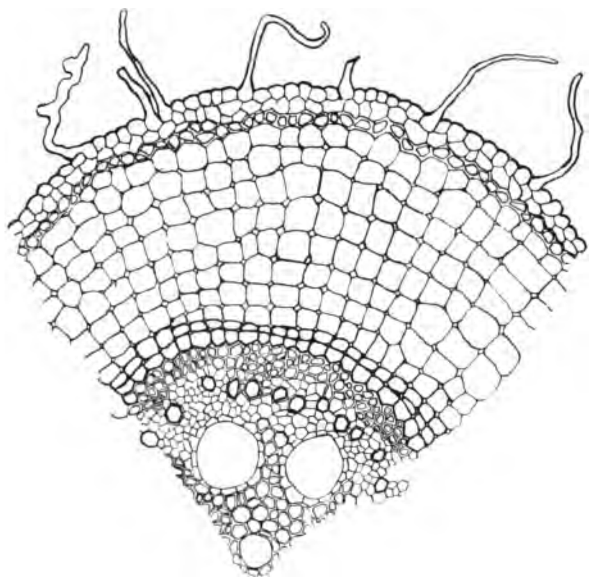

FIG. 2.

Transverse section through a root of the sugar-cane in the region of the root-hairs. It clearly shows the division of the root into two parts:—(1) The *central cylinder* showing the large openings or *vessels*, and (2) the outer part consisting of thin-walled cells and the outside layer of cells—the *piliferous layer*, from which originate the tubular outgrowths—the *root-hairs*.

The cells of the central portion are of different kinds, the larger, thick-walled cells are arranged in bundles and form tubes throughout the length of the roots. These are also continuous with similar "*vessels*" in the stem and leaves. They serve for the maintenance of the shape of the root and also for the transference of water and food from the root to the stem and leaves, and are known as the *fibro-vascular bundles*.

By carefully looking at Figs. 2 and 3 it will be seen that many of the cells of the outermost or *piliferous layer* have developed into delicate thin-walled prolongations—the *root-hairs.* The root-hairs

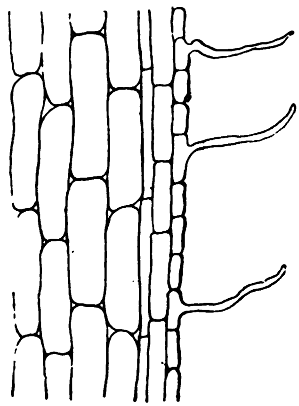

FIG. 3.

Longitudinal section through the outer part of a young root of a sugar-cane showing the origin of the *root-hairs* from the *piliferous layer.*

are seen to be mere tubular outgrowths from single cells, and contain a large sap-cavity, surrounded by a thin layer of living matter or *protoplasm.*

FUNCTIONS OF THE ROOT SYSTEM.

The root system has two functions (*a*) of fixing the plant and preventing it being blown over by the wind, (*b*) absorption of water and food material in solution from the soil. The latter function is the one we would pay the most attention to, and, as it is intimately connected with the root-hairs, it is important that we should have a clear idea of their character and uses. The older parts of roots take no part in this process of absorption, and, even in young roots, absorption seems principally confined to regions covered with root hairs.

These root-hairs are in intimate contact on the outside with the fine particles of soil and with the films of water surrounding them.

This soil water is not chemically pure water but is a very weak solution of various substances taken from the atmosphere, from the mineral salts of the earth, and from organic humus.

There are no openings into these root-hairs nor into the roots themselves, and, therefore, we have to consider how the soil water is absorbed.

In contact with the root-hairs there are two solutions, as it were, a weak solution of minerals, &c., known as soil water, on the outside of the root hair, and the cell-sap, a stronger solution, inside the root-hair. These two solutions are separated by a double wall, one composed of lifeless material—cellulose—(cotton wool is pure cellulose), and the other of living matter—protoplasm. Under these circumstances water and certain dissolved minerals pass from the weaker solution, the soil water, through both of these walls to the stronger solution, the cell-sap, in the interior of the root hairs. It must be remembered, however, that while the cellulose cell-wall is equally permeable to all substances in solution, the protoplasmic layer is able completely to exclude certain substances while allowing others to pass through more or less readily. It is also able to change its permeability according to circumstances, so that it may be said to have the power of decision, whether a certain dissolved substance may or may not gain an entrance into the root-hair. This peculiar property of the protoplasmic membranes is also held to be due to a selective power, as is shown by the fact that the roots of different plants appropriate to a greater or less degree, entirely different substances from the same soil.

This phenomenon of absorption of soil water by the root-hairs is a physical process and has been explained as due to the *osmotic pressure* of the cell-sap of the root-hairs.

From the root-hairs water and absorbed substances pass into the cells beneath the pilliferous layer and so on from cell to cell to the central conducting system of the root. From here the dilute solution of minerals passes up the vessels of the root-fibres into the vessels of the fibres of the stem. The upward current of water, &c., now passes up the stem and finally makes its way by means of the vascular bundles of the leaf-sheath and leaf into the green cells of the leaf where it becomes of use in the process of *carbon-assimilation* going on therein, which will be referred to later.

The root-hairs are, moreover, active agents in obtaining food materials, for they excrete an acid or acid salt which has the power of dissolving insoluable substances from the soil. This corroding action of root-hairs can be easily shown by the classical experiment of growing seedlings on a polished marble slab.

The reason I have dealt at such length upon the function of the root system is to show how the living root-hairs are parts of a living machinery for the active absorption of water, with the substances dissolved in it, from the soil. It is important, therefore, that planters should have a clear conception of the method of absorption from the soil, for upon the principles that underlie this process rest the whole question of cultivation of soil, application of manures, and the rotation of crops.

THE STEM.

The part of the sugar-cane that appears above ground viz., the single* shining column, is known as the *stem*, and while young is usually hidden by the sheathing bases of the leaves. When, however, the canes get older and the leaves have fallen off, we notice that the stem is made up of a number of joints differing in length, shape, and colour, according to age and variety. We have already observed that where the leaves are attached are the *nodes* (knots) and the intervals between are the *internodes*. The internodes are usually from 4 to 9 inches long and about 1½ to 2 inches in diameter. They may be cylindrical, convex or egg-shaped; that is, swollen in the middle, or concave or hollow in the middle. In the seedling B. 208 (Barbados No. 208), there is a characteristic bulging (or "forehead") just above the node, and other peculiarities may be observed in the form of the internodes of the different varieties.

In their manner of growth the series of internodes may constitute straight lines, or zigzag or curved lines. The side of the internode where the bud is placed sometimes grows faster than the other side, giving rise to an irregularity in the form of the internode and also in the habit of the cane. Further, where a cane leans over or is

* Forked sugar-canes are sometimes met with. A specimen from St. Kitts is figured in the *Agricultural News*, Vol. I., p. 115.

Branched canes are sometimes caused by the destruction of the terminal bud and the subsequent development of lateral shoots.

blown down, the internodes singly or collectively are capable of thickening on one side so as to gradually allow the cane to become erect again.

In some cases, immediately above the bud, there is observed a *groove* which varies in depth and length in the different varieties, and would appear to be in some way correlated with the size and shape of the bud.

As to the colour of the internodes, there is an infinite variety. There are white, yellow, green, reddish-brown, purple, violet, and almost black canes. There are also striped or ribbon canes. The ribbon canes may be yellow with red or green stripes, reddish with green or black stripes, or greenish with whitish stripes. In rare instances, a ribbon cane has been observed with the number of stripes gradually lessening in number from below upwards. The upper joints, even after exposure to the light, have remained without stripes or markings of any kind. There are also canes with irregular blotches of white, red, or purple.

The stripes or blotches may be caused by a "bloom" or superficial layer of wax; or, by coloured cell-sap. The latter only is permanent. It is important in describing the colour of canes to speak only of the colour of the well-grown mature internodes, which have been fully exposed to the influence of light.

The colour of young or unexposed internodes is markedly different from that of matured and exposed internodes. The change of colour continues even after the period of ripeness. Over-ripe canes or those growing along the edges of the fields sometimes show not only deeper colours, but often another tone of colour. It is interesting to illustrate the influence of light on the colour of canes by covering a freshly exposed internode with a piece of tin-foil in which letters or figures have been cut. After a few days, remove the tin-foil, and it will be noticed that, whereas the part of the internode that has been covered has retained its former colour, the letters or figures have changed colour; and in the case of red or purple canes, have assumed a deep reddish or purplish tint. Colour has been used as a basis of classification amongst canes, but it alone cannot be accepted as a distinguishing mark especially in closely allied varieties.

A useful distinguishing mark in sugar-canes is the size, shape, or colouring of the *buds* or "eyes." As you are aware, the buds

are arranged alternately along the stem immediately above each node. On dissection of a bud, it will be found to consist of a large number of overlapping layers or scales. These scales are designed to protect the young growing apex in case it may be required to carry on the life of the cane. In the early stages of growth the buds are closely invested by the lower portion of the leaf-sheath, and are devoid of colour. After the leaves fall the buds usually partake of the colouring of the internodes; but after long exposure the outer scales become brown and rusty. As regards size, they may be small and flat, or large and round. The swollen character of some buds may be due to a morbid condition; but there are canes, such as B. 208 and Sealy Seedling, that normally have large and prominent buds. After flowering, or if exposed to moist conditions, there is an undesirable tendency in such canes to become branched through excessive development of these buds.

Occasionally, in so-called "male" canes, buds may be few or absent; in others they may be displaced from the side to the middle of the internode, while in rare cases two or even three buds may appear at the base of the same internode. This is noticeable in canes about to become forked. (See *Agricultural News*, Vol. I., p. 115.)

At the upper end of the internode, immediately below the node, there is usually present a whitish band caused by a secretion of wax. The *wax-band* is usually white, irrespective of the colour of the internode. In the early stages of growth this layer of wax may cover the whole internode, and may be protective in character, in that water flows off the outside "peel" of the cane without wetting it. The appearance of the wax layer under the microscope is shown in Fig. 4. It will be observed that the band consists of numerous vertical rods of wax placed closely together.

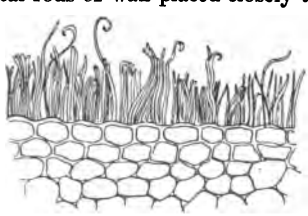

FIG. 4.

Transverse section of the *wax-layer* immediately below the node, showing wax incrustation in the form of small erect rods.

At the lower end of the internode, placed on the same horizon as the bud, is the ring of "sleeping roots." This is characterised by a dotted appearance showing the points in the "peel" or epidermis where each root will emerge. The rows of sleeping roots may vary from one to four ; near the top of the cane they may be reduced to a single row.

Throughout the whole length of Java cane (*Teboe glonggong*) there is normally but one row of sleeping roots at the lower end of each internode.

Anatomy of the Stem.

If we cut a thin transverse section through the internode of the stem, and examine it under a microscope, we see a markedly different structure than was seen in the root. We see no division between central cylinder and outer part, as we did in the root. (Fig. 5.)

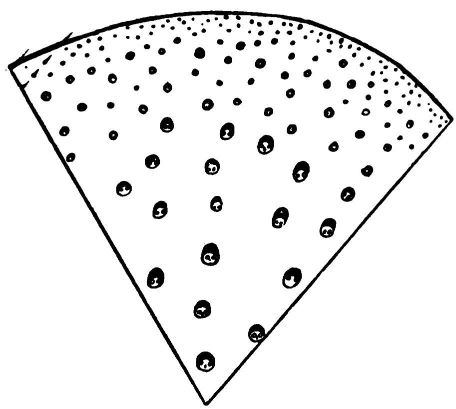

Fig. 5.

Diagrammatic drawing of the appearance of a thin section across an internode, showing the *fibro-vascular bundles* dotted about irregularly in a general *matrix*.

The whole section is seen to be made up of a general *matrix* of thin-wall cellular tissue. The cells of this matrix are more

or less six-sided, not unlike the cells in honey-comb. These are the *sugar-cells*, for in them is contained the fluid in which are dissolved the sugar and other products found in cane-juice.

Distributed irregularly throughout this cellular matrix are groups of other and more highly differentiated tissue, called *fibro-vascular bundles.* They represent, after the grinding of the sugar-cane, the "megass" of the planter. These, as you remember, are continuous with those in the central cylinder of the roots. In the internodes the bundles are more or less parallel, and do not communicate with one another, but at the nodes they freely branch, the branches of one running into the branches of another. Bundles, similar to those above noticed, pass from this anastomosis in the nodes into the buds (Fig. 6), and also into the leaves. We, therefore, see that there is a complete system of continuous tubes throughout the whole plant, and this serves for the distribution of food material, &c.

FIG. 6.

Diagrammatic drawing to show the parallel arrangement of the *fibro-vascular bundles* in the internodes and their repeated branching in the region of the nodes. Many branches may also be seen passing into the *buds.*

On the outside of the whole stem we get a layer of special cells, which are called the "peel" or *epidermis*. The outer, walls of these cells are thickened, contain particles of silica, and are quite impervious to water.

Under the epidermis we get several layers of thick-walled cells which form the *mechanical tissue*, and they seem to strengthen the cane and so prevent its being broken.

Now, if we examine a highly-magnified section of one of the fibro-vascular bundles, we shall notice that it is composed of differently-shaped cells. (Fig. 7.).

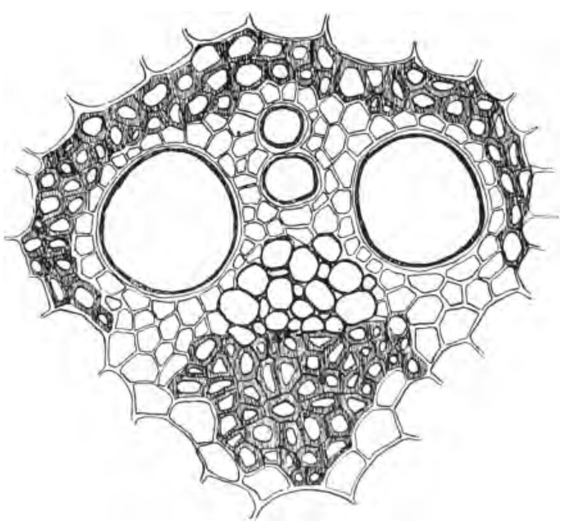

FIG. 7.

Transverse section of a fibro-vascular bundle of a stem of sugar-cane, showing the *vessels* as the larger openings, the *sieve-tubes* as the well marked openings below and nearly between the vessels, and the thick-walled cells—the *fibrous portion*, which assists in the strengthening of the stem.

The larger openings represent the *vessels* or tubes through which the water from the roots is said to travel upwards to the leaves, thus conveying the food material from the soil. The smaller but distinctly marked openings represent the *sieve-tubes.* These are long cells with partition walls at different distances. They are assumed to be the means whereby the elaborated food material coming from the leaf is distributed downwards throughout the whole of the plant. As a broad generalization it may therefore be stated that the food material is conveyed up the stem through one set of tubes—the vessels, and that it passes down through another set—the sieve-tubes. There may also be seen thick-walled cells. These form the *fibrous portion* of the bundle and help to strengthen the stem.

The arrangement of tissues above described applies only to the internodes. In the nodes we have very different conditions, arising from closely packed fibro-vascular bundles, and an interlacing of those coming from the leaves and buds. The sugar-cells in the nodes are almost entirely absent. This has a practical meaning. It can easily be understood that when the internodes are short and nodes numerous, the canes will yield less juice than where the internodes are long and the nodes few.

Functions of the Stem.

The various functions of the stem have been noticed in the examination of its anatomy, but they may be summarised here. The first function noticeable is that the stem ascends into the air in order to allow the leaves as much access to light and air as possible. The importance of this will be noticed later, when the functions of the leaf will be discussed.

The second function of the stem is to carry, by means of its fibro-vascular bundles, materials to and from the leaves, and thirdly, the large thin-walled cells that form the general matrix serve for the storage of that product for which the sugar cane is cultivated—cane sugar. The sugar is stored in solution in the juice, and not in solid crystals such as are met with in some other plants.

Leaves.

The leaves consist of *sheath* and *blade*. The sheaths are split and envelop the cane in the young stage, thus offering protection to the stem. (Fig. 8.)

Fig. 8.

Portion of stem of sugar-cane, showing *leaf-sheath* enveloping the stem, stinging hairs, and *leaf-blade* with *mid-rib* down the centre.

The blade grows out from the cane exposed to the sun and air. It is in the blade that, practically, the chief work of the sugar cane is carried on. The blade of the leaf is flat, and if we examine its under surface we notice that in the centre, throughout its whole length, is a prominent ridge—the *mid-rib*. Parallel to this are smaller ridges—the *veins*. The mid-rib and veins contain the fibro-vascular bundles of the leaf, and these are continuous with those already noticed in the stem.

Anatomy of a Leaf.

If we examined a section of a leaf we should notice that upon the upper and lower surfaces is a layer of cells known as the *epidermis.* Between some of the cells of the epidermis we get small openings which allow a direct communication between the tissues inside the leaf and the outside air. They are known as the *stomata.*

The general body of the leaf is made up of thin-walled irregularly shaped cells arranged in a network, with larger spaces between them. These cells contain small bodies that contain the green colouring of plants—the *chlorophyll* or *leaf-green.*

The large intercellular spaces contain air and, therefore, practically every cell of the leaf is thus placed in direct contact with the air.

Functions of the Leaf.

The leaf is often spoken of as the workshop of the plant and, therefore, we should clearly understand its uses.

If we analyze a cane-leaf by the usual chemical methods, we find that it is composed of mineral substances, nitrogen, carbon, oxygen, and hydrogen, as well as traces of other elements. The mineral matter is that portion which remains in the form of ash when a cane-leaf is burned. We have seen that mineral substances have come from the ground, as has also the nitrogen ; but all the matter of a carbonaceous character has been obtained by the leaves from the air.

In the atmosphere carbon exists in combination with oxygen as carbon dioxide. This passes, with the other gases, into the intercellular spaces of the leaves. Finally, it passes through the cell-walls into the cells themselves where, in the presence of sunlight, the carbon is used in the construction of the complex materials of the plant, and oxygen is returned to the air.

This change will only go on under certain conditions, and it is essential that the green-colouring matter be present in the cells, and we must have sunlight. This process is called *carbon assimilation*, and is perpetually going on in all green parts of the plants when the conditions are favourable.

Through the agency of the leaves, therefore, carbon from the air is combined with water to form more complex substances. The first product formed, that can be readily recognised, is starch. When assimilation stops, as it regularly does at night, then the starch is converted into soluble carbohydrates (glucose, cane-sugar, etc.) which pass into the stem. That which is not combined with nitrogen to be used up as food material for the growth of the plant itself is stored up as reserve material in the thin-walled cells of the general matrix of the stem. So far, the actual transfer or conversion of starch into glucose and of glucose into cane sugar has not been worked out thoroughly in the sugar-cane, but it has clearly been shown that it is necessary to have a large leaf system in successful cultivation of sugar-cane—hence the clearing of the land of all shade trees in order to admit as much sunlight as possible combined with a large leaf development.

Another function of the leaf worthy of mention is that known as *transpiration*. From the cells of the leaf, which are in direct contact with the air, a considerable evaporation of water takes place. This is the process of transpiration, and is of great importance, as it is one of the factors that determines the upward current of the water and food materials in solution from the roots to the leaves, where they are needed to carry on the process of assimilation.

The Inflorescence.

Some varieties of sugar-cane now under cultivation produce more or less freely an elongation of the stem which bears the "arrow" or *inflorescence*. This inflorescence varies from 2 feet to 3 feet in length, and is repeatedly branched. The ultimate branches bear laterally a number of *spikelets*, each of which contains a single flower. The spikelets are arranged in pairs, one being stalked and the other not, at distances of a little more than $\frac{1}{8}$ inch on alternate sides of the slender long branches.

Anatomy of a Flower.

If we take one of these spikelets and examine it under a dissecting microscope, we find on the outside three scale leaves. The two outer are stiff and vary in colour from green to purplish, while the innermost, which is packed inside one of the outer (Fig. 9), is thin,

white, and membraneous. The two outer leaves are known as the *glumes*, and the thin inner one is called the *palea*. These scale-like structures protect the more delicate inner parts of the spikelet in its young stage.

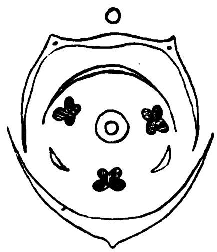

FIG. 9.

Floral diagram of the sugar-cane, showing the two *glumes* on the outside, inside the upper of which is the *palea*. The two small scales are the *lodicules*, and towards the centre of the diagram are seen the three *stamens* and the *ovary*.

At the base of these three scales may be found, on careful dissection, two minute structures. These are known as the *lodicules*. They are scale-like in appearance, and are said to take up water when the flower is ripe, and to swell, so as to push the glumes and palea apart, thus causing the flower to "open."

Finally in the centre of the spikelet we come to the most important parts. These consist of the *stamens* and *pistil* (Fig. 10).

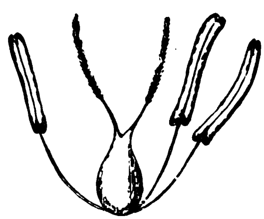

FIG. 10.

Diagram showing the *ovary* in the centre with its two *stigmatic plumes* and the three *stamens*, each of which consists of a *filament* and a box-like structure called the *anther*.

The stamens are three in number and each consists of a slender stalk and a kind of small box on the top. This small box-like structure or *anther* varies in colour from yellow to reddish-yellow, and contains the *pollen grains*, inside of which the male reproductive cells of the plant are found. The pistil consists of a swollen *ovary*, quite at the bottom of the flower, surmounted by two red feathery *stigmatic plumes*. In the ovary is a single body or *ovule*, which contains the female reproductive cells of the plant. The arrangement of the different parts of the flower may clearly be seen in the floral diagram given in Figure 9.

When one of the anthers ripens it bursts and in this way scatters its contents, the pollen grains. These are blown about by the wind and may chance to light upon one of the sticky feathery stigmatic plumes at the top of the ovary. They then germinate and put out small tubes which grow downwards to the ovule, where we get a fusion between the male and female cells. This fusion is the process of *fertilization*.

The ovary, after fertilization has taken place, becomes the *fruit* or grain, but is commonly spoken of as the "seed" of the sugar-cane. From these "seeds" young seedling canes may be grown, and so a race of new seedling canes may be raised and established.

NEW SEEDLING VARIETIES.

It would appear that canes probably grown from seed were observed at Barbados in 1848 and 1850, and the question respecting the possibility of producing seedling canes in the West Indies was raised at various times between 1859 and 1888. In the latter year it was definitely settled by Messrs. Harrison and Bovell that seedling varieties could be successfully raised in the West Indies. A similar announcement was made in Java in 1887 by Dr. Soltwedel.

Previous to 1887 and 1888, it was generally thought that the sugar-cane, in common with the banana and other tropical plants, had lost the power of producing fertile seed through being propagated by cuttings for many generations.

Since then systematic attempts have been made to raise new varieties of canes from seed. The problem before us is to effect the cross-fertilization of the sugar-cane under control, that is,

in such a way that we can cross two well-known varieties and so blend their characteristics in the hope of obtaining new seedlings with improved qualities.

Up to this time (1903) all the new varieties of canes in the West Indies that have been raised from seed are the results of chance fertilization. We may know the seed-bearing parent, but not that which produced the pollen. In the future we hope to be able to control the sources of the pollen, and, therefore, know definitely the pedigree of the new seedlings. The difficulties are considerable, mainly owing to (1) the microscopic size of the flowers, and (2) the fact that they are borne at the end of a fragile stalk some 13 to 16 feet from the ground. It is hoped to overcome these difficulties and thus produce a race of pedigree seedling canes.

SELECTION OF SEEDLING CANES.

At the present time we have large areas of seedling canes under experiment in the West Indies. In Barbados alone there are about 1,000 acres, and experiments are also being conducted in Demerara, Antigua, St. Kitt's and Trinidad.* The officers in charge of these stations are putting forth their best energies in order to obtain definite comparative results amongst the new seedlings.

The Bourbon cane was once universally cultivated throughout the West Indies, but, owing to attacks of disease, its cultivation is being abandoned and newer varieties substituted. It is not hoped to obtain one single cane to suit all situations, for the variations of soil and climatic conditions of the West Indies render it necessary to have many kinds of canes differing in their requirements. The results at the experiment stations are being regularly published so as to bring before planters such canes as promise to be of benefit to them.

The seedling canes are distributed on experimental plots in widely different areas and under different conditions, and are grown in competition for a number of seasons before any definite conclusions are drawn as to their relative value and before they are recommended to planters for final trial under estate conditions.

It must then be left to the planters themselves finally to select those which they think suitable for their cultivation, as a seedling

* At British Guiana, the area under seedling canes is about 20,000 acres.

may give very good results in one soil but prove an utter failure in another. It is for the planters, in whose interests these experiments are carried on, to make the best use of them, and I ask for their active assistance in the work in which we are engaged.

There are at present some seedling canes that are able, through increased vigour of growth, to withstand the attacks of certain diseases, and to produce a larger yield of sugar per acre than those now cultivated. We ask that these should be given a fair trial under estate conditions. The planters may then find that some of the seedling canes have a real economic value, in that they are capable of giving increased yields of sugar at a lower cost.

SUMMARY.

In summing up the uses of the various parts of the sugar-cane, we have noticed that the roots fix the plants in the soil and supply the mineral and nitrogenous food in solution to the plant.

The leaves, we noticed, were the factory of the plant. They obtain all the carbonaceous food required and throw off the surplus water that may have been taken up by the roots. They are also capable, under the influence of sunlight, of manufacturing the food necessary for the building up of the tissues of the cane and also the food stored as reserve material in the stem—*i.e.*, the cane sugar.

The stem is, therefore, the store-house of the plant, supports the leaves and so assists them in spreading in sunlight.

The flowers and buds are active agents, more or less, of service in propagating the cane plant, and also in enabling us to obtain new varieties capable of further improvement.

In conclusion, I must confine myself to essential points only—such points as the planter directly deals with, and which he may turn to his own advantage.

Taking first the root system, it is noticed that the roots of the sugar-cane have a tendency to keep near the surface as long as they can obtain moisture and are not too crowded ; but the best results are probably obtained only when the root system strikes deep down and reaches as near as possible the line of permanent moisture. Under suitable conditions the roots of the sugar-cane

will travel to depths of three or four feet, but there is, no doubt, as much variation in the habit of root growth as there is in the stem and leaves. A cane that develops the power to dig down in search of food and moisture would be much better adapted to dry districts than one which is capable of only producing surface roots.

The effective parts of the root system are the fine rootlets with their root-hairs. The latter are organs which absorb moisture from the soil, and, with the moisture, plant-food in solution. It must be borne in mind that the root-hairs can only take in food in solution, and they must come into intimate contact with it—a point of great importance in the cultivation of the soil and also in the application of manures. An excess of moisture in the soil is, however, detrimental to the maximum development of root-hairs, and therefore it is necessary to keep the land well drained. It can be understood also how important it is that the soil should be properly cultivated in order to allow the roots to penetrate to a considerable depth. They are then capable of taking up a large amount of plant-food and are also able to withstand long spells of drought.

In short, I cannot advise planters too strongly to make a careful study of all the different parts of the plant, they are cultivating, for then they will realise that the central point in all their efforts is the plant, and it is only by a knowledge of its needs and requirements that the planter can clearly decide such matters as the choice of soils, the most successful methods of cultivation, the economical application of manures, and by such means obtain the highest returns.

LECTURE II.

SOILS AND MANURES IN RELATION TO THE CULTIVATION OF THE SUGAR CANE.

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In the first lecture of this series we learnt that it was in the green leaf of the cane plant that the raw materials were brought together from which sugar was constructed; we learnt that some of these materials were taken from the atmosphere and that others were taken from the soil; we learnt that the raw materials, which were actually used in building up and constructing sugar, were carbonic anhydride, a colourless gas taken in by the small apertures in the leaf from the atmosphere, and water taken up by the roots from the soil and transmitted to the leaf by the stem. We learned that this sugar so constructed was conveyed away from the leaf to certain minute bags, botanically termed "cells," of which there is such a large number in the stem, and there stored up by the cane plant for future use in building up its new shoots, in building up its roots, and in the enlargement of the cane itself; and we learned that the ultimate reserve which is stored up in the cane at the end of the period of growth was stored up for the purpose of constructing its seed by means of which, in the primitive state, it is probable that the cane plant propagated itself and perpetuated its species.

Besides carbonic anhydride, the colourless compound gas from the atmosphere, and water from the soil, the cane also requires nitrogenous compounds in the form of nitrates, as well as mineral substances, and these are obtained in very weak solution from the soil. All these raw materials are absolutely necessary for the existence of the cane plant. Taking them as a whole we find that carbonic anhydride is obtained from the atmosphere, and that water, nitrogenous compounds and mineral food are obtained from the soil.

Now the planter looks at the cane plant from a somewhat different point of view from which the cane plant would regard itself. The planter regards it as a factory for making sugar ; it is therefore natural that he should aim at supplying these raw materials in the most favourable form and in the maximum quantity so far as it can be made use of by the cane plant for the purpose of turning out the maximum quantity of manufactured material, namely, sugar. He will ask me in what way he can influence the supply of the plant food—the raw material—to the cane. If he turn his attention to the atmosphere, he will conclude that this is quite beyond his control ; he cannot increase or modify the carbonic anhydride gas, neither can he increase the amount of sunlight given to the cane, nor increase nor modify the temperature of the atmosphere in which the cane lives. Consequently he will have to confine his attention entirely to the cane plant itself and to the soil in which it lives. He will devote his attention to the cane plant with a view to securing the most efficient and healthy kind of cane and also with a view to finding a cane which will produce the maximum crop of sugar under favourable conditions. And when he has done that, he will devote his attention to the soil. He will try and learn all that he can about the soil with a view to enabling the cane to give him a maximum of sugar. It is upon the soil that I have the honour of addressing you specially this afternoon.

No apology is necessary in a course like this to planters to justify a careful study of the soil. We all know that something like 13*s*. 6*d*. on the average is spent annually for the production of a ton of cane in Barbados. We know, too, that something like £3 to £4 per acre is spent on the soil on artificial manures, that large sums are spent annually in forking and ploughing and in other forms of tillage ; therefore it is necessary that we should understand the origin and composition, and methods of improvement of the soil. I shall treat the subject something in this order. I shall first of all

deal very briefly with the origin of soils and the substances from which they are formed; I shall then turn to the actual chemical constituents of the soil; I shall then take up the study of the physical properties of the chief constituents of soils, followed by an account of the history and usefulness of certain organisms occurring in the soil. I shall then deal with the improvement of soils, this will include an account of the effect of drainage and tillage, of the application of farmyard and artificial manures, and of the rotation of crops.

ORIGIN AND FORMATION OF SOILS.

Soils are formed by the activity of certain natural agents upon rocks. These agents are the atmosphere, rain water and flowing water, alternating heat and cold, the influence of vegetation upon primitive soil, and finally the activity of certain organisms in the soil—"biological" activity, we call it—because it is the activity of living organisms that have their abode in the soil.

THE ATMOSPHERE AND OXIDATION.

With regard to the action of the atmosphere upon rocks, the atmosphere consists of three gases—nitrogen, oxygen, and carbonic anhydride: and in 10,000 pints of air we will find approximately 7,906 pints of nitrogen, 2,090 pints of oxygen, and 4 pints of carbonic anhydride.

I have upon the table two experiments to illustrate the composition of atmospheric air. The bell-jar (Fig. 11) is standing over water, and above the surface of the water is supported an iron cup containing a fragment of phosphorus. I remove the stopper of the bell-jar and touch the phosphorus with a hot iron; it at once ignites. I replace the stopper, and you will notice that after a time the phosphorus ceases to burn, the water rises in the bell-jar, and white fumes cover its sides. Upon cooling you will see that the water rises so that it occupies the lower fifth of the jar, and upon examining the residual air in the jar with a lighted match, you will see that the match is extinguished. The phosphorus has combined with the oxygen (one-fifth) of the air to form phosphoric anhydride, and the nitrogen (four-fifths) is left behind.

In the second experiment (Fig. 12) I have an arrangement for drawing atmospheric air through lime-water. After a time the lime-water is rendered milky by the formation of carbonate of lime (chalk)—a compound of the lime dissolved in the water and of the carbonic anhydride gas in the atmosphere. This carbonate of lime being insoluble in water comes down as a white precipitate (powdery solid substance).

It is the oxygen in the air which is the active constituent that helps to form soils from rocks, and as the oxygen is not confined to

FIG. 11.

The burning phosphorus has consumed the oxygen which forms one-fifth of the volume of the air, and the water has therefore risen to the first mark in the bell-jar.

the air, but is present in the soil itself, I shall claim your attention for a few moments while I deal with the peculiar nature of this activity of oxygen upon rocks.

If an iron hoop be allowed to remain exposed to the atmosphere you all know it rusts, that is to say, a layer of rust forms on it, which gradually thickens and may penetrate the inside of the iron, which then crumbles to pieces and falls into powder. That iron rust is caused by the oxygen of the atmosphere combining with the iron of the hoop to form a substance called "iron oxide," which is a compound of iron and oxygen. It is a very peculiar and important property of oxygen to combine with a large number of other elements to form combinations or compounds called "oxides"

and there is a large number of these combinations of oxygen with other substances to be found in the soil. In fact, oxides are such important substances that I have upon the table for your inspection a number of specimens of oxides that are found in the soil. First we have this compound of oxygen and iron which forms rust or iron oxide, then we have aluminium oxide (alumina), a white rust formed by the combination of the metal aluminium with oxygen. This

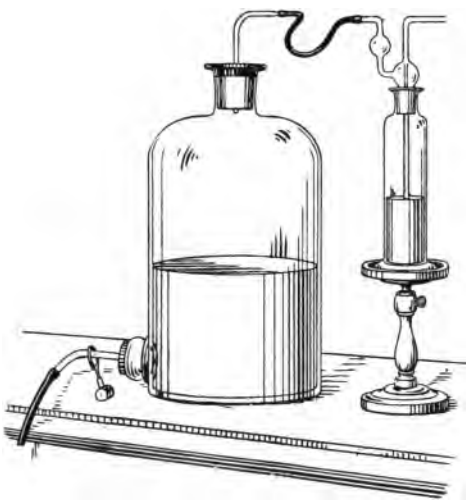

FIG. 12.
Shewing apparatus for aspiring air through lime-water.

oxide is actually being formed as a white incrustation upon the aluminium stand on this table. The most important oxides or compounds with oxygen are :—

Iron oxide—a compound of iron and oxygen.

Aluminium oxide (alumina)—a compound of aluminium and oxygen.

Calcium oxide (lime)—a compound of calcium and oxygen.

Magnesium oxide (magnesia)—a compound of magnesium and oxygen.

Manganese oxide—a compound of manganese and oxygen.

Potassium oxide (potash)—a compound of potassium and oxygen.

Sodium oxide (soda)—a compound of sodium and oxygen.

Phosphoric anhydride (phosphoric acid)—a compound of phosphorus and oxygen.

Sulphuric anhydride (sulphuric acid)—a compound of sulphur and oxygen.

Carbonic anhydride (carbonic acid)—a compound of carbon and oxygen.

Nitric anhydride (nitric acid)—a compound of nitrogen and oxygen.

Silicic anhydride (silica)— a compound of silicon and oxygen.

Several of these compounds are on the table ; and upon the list above I have italicised the oxides that are, as we shall subsequently learn, essential to the plant as food.

The substances iron, aluminium, calcium, magnesium, &c., as well as the oxygen with which they are combined are called *elements* because they are simple substances that cannot be split up by any known chemical means, and you will now clearly understand that by the term oxide and the term anhydride we mean a compound of one or other of these elements with oxygen. Some seventy of these elements are known, but those specified upon this list are by far the most important and abundant in the formation of the earth's crust.

I may here point out that analytical chemists frequently use the terms phosphoric acid, sulphuric acid, carbonic acid as respectively identical with phosphoric anhydride, sulphuric anhydride, and carbonic anhydride—I mention the fact now in order that you may not be subsequently confused in the course of my lectures.

The importance of all this with regard to the formation of soils is that oxygen combines with certain constituents found in rocks, particularly with iron, to form powdery "rusts" which crumble down and cause the mass of rock to drop into fragments, and these fragments constitute some of the most important constituents of soil.

THE ACTION OF WATER.

Turning to the next agent in the formation of soils we have the action of water upon rocks. Water as you know dissolves various substances. If you shake up sugar with water the sugar dissolves or "melts"; if you shake sulphate of ammonia with water it dissolves. Water is a very universal solvent; it dissolves more or less the great majority of substances that exist on the surface of the earth. Most of them dissolve exceedingly slowly, but rain water as it passes through the air takes with it some of the carbonic anhydride existing in the air, and water so impregnated is a much more powerful solvent of rocky substances than pure water. Consequently, rain water is quite a powerful solvent of rocks. "Soda water" is simply water impregnated with carbonic anhydride, and it would be important if we had the time to study by means of experiments this afternoon the action on rocky substances of water impregnated with carbonic anhydride. Here is some soda water which I shake up with finely powdered limestone: the liquid which I now filter has dissolved a very notable proportion of this carbonate of lime, and, upon boiling the clear filtered liquid, the carbonate of lime comes down as a precipitate because when the carbonic anhydride is expelled by boiling, water can no longer retain calcium carbonate in solution. That is the incrustation commonly seen on your boilers when you use hard water—the object of softening water is to precipitate the carbonate of lime contained in the water so that the water freed from this substance may be "soft" and not cause the incrustation of the boilers which is seen when hard water is used. The point of all this is that when rain water acts upon our limestone rocks it rapidly dissolves the carbonate of lime of which that rock is chiefly composed, and all that remains behind is just the small portion which is not soluble, or which is much less soluble, in carbonic anhydride water: and these remains of the limestone rock, together with fragments of undissolved rock, are what form the mineral constituents of the majority of Barbados soils. Professor Harrison has estimated that in Barbados some fifty feet of coral rock have been thus dissolved by the action of rain water to form one foot of red soil. Here is a piece of granite: you see it consists of a number of small crystals. Anyone who is close to this will see that it is not a homogeneous mass but is composed of a mass of crystals. When rain water acts on a mass like this it will dissolve the soluble

constituents and will leave others which are less soluble to crumble down; and here again we shall have the nucleus of a soil. (Fig. 13.)

Alternating heat and cold also cause rocks to break down and crumble into small fragments, and so by these various agencies we have a layer of particles formed, of sizes varying from that of stones down to particles so small that we cannot measure them under the microscope. These particles form the nucleus of a primitive soil.

FIG. 13.
Some minerals that help to form soils.

The primitive soil may remain where it was formed, or it may be blown by the wind or washed by the rain to lower levels. The former is probably the case with our red soils, and the latter with our black soils.

THE ACTION OF VEGETATION.

When a small amount of primitive soil is collected certain primitive plants spring up, such as you find growing on the rocks near the sea-coast where there is a thin powdery layer of soil. And these tiny primitive plants, such as lichens and then mosses, will in time die and decay on the surface of the rocks, and in decaying they will add, as you all know, vegetable matter to that primitive soil. This layer of fine mineral particles, together with the vegetable matter, will form our first true soil.

The other agencies most important in the formation of soils are the higher plants themselves—which die and decay, adding humus and returning plant food to the soil—earth worms, and certain

minute organisms called "bacteria." When the primitive plants have lived and died alternately for some time we shall find higher plants commencing to take up their abode, and we shall find trees of the most developed kinds; these annually drop their leaves and branches, which, when decayed, form the decayed vegetable matter called "humus," a most important constituent of soils. In this manner a large accumulation of humus takes place in the virgin soils of primeval forests; and since this humus is of an acid nature and is also continually, as we shall hereafter learn, giving rise to the formation of carbonic anhydride, the rain water that percolates through the soils of primeval forest is a most potent and rapid agent in the disintegration or crumbling down of the underlying rocks, adding rapidly to the thickness of the soil.

I will leave the subject of earth worms and bacteria for the present and pass at once to a study of the composition of the soil.

Composition of Soils. Mechanical Analysis.

Soil, as I mentioned a moment ago, consists of the collection of fragments of rocks of different sizes. That brings me to the subject of the mechanical analysis of the soil. Mechanical analysis, as it is carried on by most of the chemists of the United States of America and many chemists in Europe, consists of the separation of these particles into different grades of sizes. That separation is accomplished first of all by using different sized sieves. We use in the Government Laboratory here four sizes of sieves—first a sieve in which the meshes are three millimetres apart, allowing all particles whose diameter is three millimetres and less to pass through; then we use a sieve in which the meshes are one millimetre apart, and which allows particles below one millimetre in diameter to pass through;—one millimetre being one twenty-fifth part of an inch. Hence the largest particle that can pass through this sieve is a particle less than one millimetre in diameter. After sieving, the larger particles remain above, and from these we get particles of diameters ranging from three millimetres to one millimetre, and we call this "gravel." Upon the third sieve of which the meshes are 0·5 millimetre apart, remain particles from one millimetre to 0·5 millimetre in diameter, and we call these particles "coarse sand." The meshes of the last sieve are 0·25 millimetre apart, and the particles that remain upon it range in diameter from 0·5 to 0·25 millimetre, and the residue remaining on the sieve we call "medium

sand." After that the particles are too small to be separated by sieves; therefore we put them into a vessel with water and stir it up. When this is done the larger particles of the soil sink almost immediately, but the finer ones remain suspended in the water for some time. The coarse ones sink first; these we call "fine sand." By repeated sedimentation, which may last five or six days or may have to go on for weeks, we separate the finer particles into

FIG. 14.

Some of the products of a mechanical analysis of the soil.

Stones. Gravel. Coarse Sand. Medium Sand.

"fine sand," which goes down to 0·05 of a millimetre; "silt," which goes down to 0·01 of a millimetre: "fine silt," which goes down to 0·002 of a millimetre, and then we get particles below 0·002 of a millimetre—so fine that they cannot be measured under a microscope, and they are called "clay." All these sizes are microscopic sizes. The last two of these, namely, "silt" and "clay," taken together we call "agricultural clay," because, as we shall learn, it is

the most important part of the soil in forming a judgment as to its general characters in regard to drainage and tillage.

I have placed upon the table for your inspection a number of bottles (Fig. 14) containing a complete set of these particles. They will serve to illustrate clearly the results of a mechanical analysis of a soil.

Finally in this connection I draw your attention to the term "fine soil" or "fine earth." Either of these terms are used to signify that portion of the field sample taken for chemical analysis, the portion so taken is all that passes through a sieve whose meshes are 0·5 millimetre (that is one-fiftieth of an inch) apart, that is medium sand down to and including clay. This plan is adopted in the belief that the plant roots mainly draw their food supply from these small particles, which, as we shall presently see, present a much larger area of surface for contact with the roots than do the larger particles.

MECHANICAL ANALYSIS.

—	Size of Particles in Millimetres.	Percentage.	—
Gravel	mm. 3 to mm. 1		
Coarse sand	1 „ 0·5		
Medium sand	0·5 „ 0·25		
Fine sand	0·25 „ 0·05		
Silt	0·05 „ 0·01		
Fine silt	0·01 „ 0·002		Agricultural clay.
Clay	0·002 „ —		
Fine soil	5 „ —		

With this practical mechanical analysis (Figs. 14, 15, 16, and 17) of the soil under your eyes you cannot fail to know the meaning of a mechanical soil analysis as performed at the Government Laboratory.

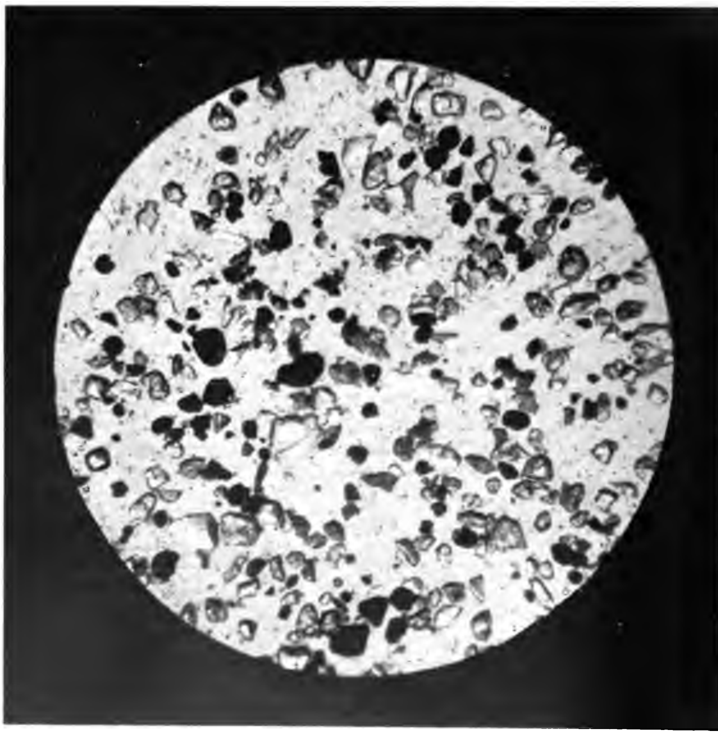

FIG. 15.

Mechanical soil analysis. Fine sand (magnified).

PROXIMATE CONSTITUENTS OF SOIL.

I now turn to the chemical composition of the soil. The most important constituents of soils are silicious sand, clay, calcium

carbonate, or chalk (which you know locally under the name of stone), and humus or decayed vegetable matter. These four substances are the most important constituents of the soil, and they contain all the mineral plant food of the soil. Silicious sand consists simply of the oxide of silicon, and of certain little particles of

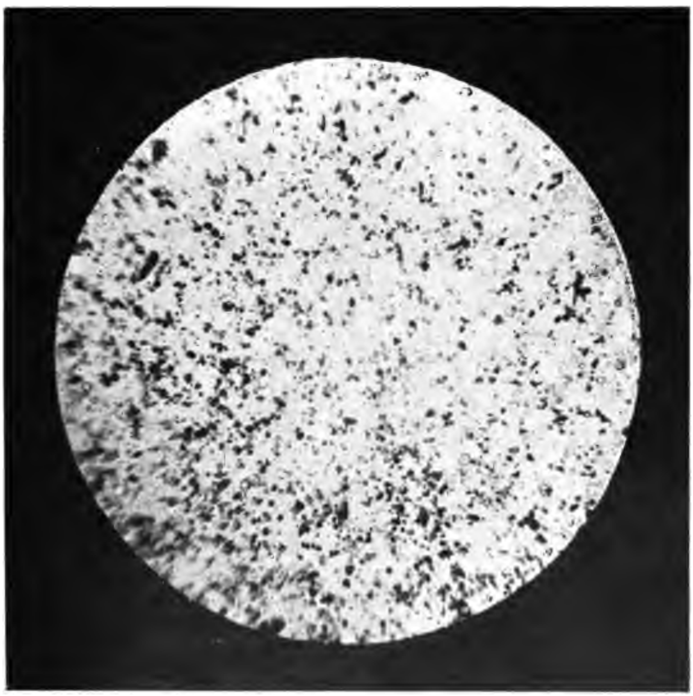

FIG. 16.

Mechanical soil analysis. Silt (magnified).

rock and other insoluble silicates which neither water, carbonic anhydride, nor even strong acids can dissolve except slowly and with great difficulty. It is therefore believed to supply no plant food at all.

The next substance, clay, is a chemical compound, containing silica, alumina, iron oxide, water, potassium oxide, sodium oxide, calcium oxide, and magnesia. Certain of these, as you will observe, are italicised on the diagram before you,

Water.		
Potassium oxide.	**Alumina.**	**Silica.**
Sodium oxide.	*Iron oxide.*	
Calcium oxide.		
Magnesium oxide.		

TABLE showing the composition of agricultural clay.

because they are essential constituents of plant food and essential to the proper life and well being of the cane plant. You will therefore see that clay is a most important substance and that it supplies some of the most important constituents of plant food.

The next substance mentioned, namely, calcium carbonate, supplies another essential constituent of plant food, namely, calcium oxide or lime; calcium oxide is as we have seen, also found in clay. Calcium carbonate—as its name indicates—consists of calcium oxide and carbonic anhydride, the gas already mentioned.

Now humus, the last of the substances which are important as constituents of soils, is a compound containing carbon or charcoal, oxygen and hydrogen, and, lastly, and most important of all, the element called nitrogen: and it is humus that is the chief source of the nitrogenous food of plants.

Having seen what are the most important constituents of soils, let us turn to the chemical analysis of soils. (*See* Table, p. 42.)

In this chemical analysis you do not see sand, clay, chalk, or humus, because we do not separate them as such, but estimate the ultimate chemical constituents whether supplied by each or all of these substances: but, as we have seen, some of these ultimate chemical constituents are supplied by clay, some by chalk, and some by humus, and for the purpose of studying the present fertility

and the future capabilities of the soil when subjected to tillage, we make a chemical analysis showing the amounts of the ultimate chemical constituents of plant food.

FIG. 17.

Mechanical soil analysis. Fine silt (magnified).

The records of analyses before you are records such as are issued from the Government Laboratory of this colony.

In this case I have italicised the items that are essential constituents of plant food.

CHEMICAL ANALYSIS OF FINE SOIL.

Results calculated to soils dried at 100° C.

—	Soil Per cent.	Soil Approx. lb. Per acre.
Insoluble silicious matter	59·122	1,773,660
Soluble silica	·190	5,700
**Potassium oxide*	·052	1,560
Sodium oxide	·085	2,550
Calcium oxide	1·000	30,000
Magnesia	·864	25,920
Manganese oxide	·302	9,060
Ferric Oxide and alumina	24·080	722,400
†*Phosphoric anhydride*	·070	2,100
Sulphuric anhydride	·223	6,690
‡Carbonic anhydride	·170	5,100
§Combined water and organic matter ...	14·082	422,460
Total	100·240	3,007,200
*Containing *potassium oxide* soluble in 1 per cent. citric acid.	trace	—
†Containing *phosphoric anhydride* soluble in 1 per cent. citric acid.	·009	270
‡Equal to *carbonate of lime*	·386	11,580
§Containing *nitrogen*	·272	8,160
§Containing humus	3·292	98,760

NON-AVAILABLE PLANT FOOD.

As a result of the careful study of soils it has been ascertained that plant food exists in three forms : one is a form so incapable

of being dissolved by rain water or other solvent, and the possibility of its being of any use to the plant is so remote, that it is spoken of as "non-available."

Potential Plant Food.

Next we have plant food which I will call "potential" plant food, that is, plant food existing in the soil which will not be immediately available to the plant, but which the operations of tillage and cultivation may in the future render available to it; it is not at the present moment capable of being dissolved by rain water or the acid exudation of the roots of the plant, but is capable by tillage and cultivation of being converted into a form which can in the future be dissolved.

Available Plant Food.

The third kind of plant food is what is called "available" plant food, that is to say, the amount of the various materials in the soil essential as plant food which the plant, either by means of rain water (water impregnated with carbonic anhydride) or by the acid exudation of the rootlets of the plant itself, is able to get into solution and use at once as plant food.

The chemist asks himself, how is he to find out what food is non-available, what is potential, and what is immediately available for his crops next year? To do that chemists have all agreed that the most convenient solvent for dissolving out the potential plant food from the non-available is hydrochloric acid. The chemist soaks his soil in strong hydrochloric acid in a glass vessel; this vessel is immersed during a whole day in a boiling water bath and repeatedly shaken, and at the end of that day whatever is dissolved is regarded as potential plant food which can be made available or useful to the plant by the operations of tillage and cultivation.

The next question is, how is he to find out what is immediately available? Chemists have been trying different solvents to estimate the quantity of the materials immediately available to the plant, and a few years ago Dr. Bernard Dyer made some very careful researches on that subject. He reflected that plant roots are able to dissolve certain substances which water cannot easily dissolve.

An historical experiment is described in Sach's great work on botany : a slab of marble was covered with a thin layer of soil and seed sown in the soil ; little plants grew on that soil, which was kept moistened for a few weeks, and after that both plants and soil were washed off. On the surface of the marble there was a perfect tracing or etching of the roots of the plants, because some of the calcium carbonate was dissolved off the bright surface of the marble. This shows that the plant roots exude some acid substance which is capable of dissolving what pure water cannot dissolve.

Now Dr. Dyer cut up some plant roots very finely and reduced them to pulp and extracted the sap from that pulp, and he found that the sap was acid and its activity was equal to one per cent. of citric acid, an acid well known to all of you. He then took a one per cent. solution of citric acid and tried its solvent power on some soils which were known to be rich in available potash, he took other soils which were known to be deficient in available potash. He did the same with two soils, one rich in available phosphoric acid and the other exhausted of phosphoric acid—the one had been exhausted for forty years and the other had been continually supplied, so that there was no doubt that in one he had no available phosphoric acid and in the other there was an abundance of it—and he found that the one per cent. of citric acid showed the difference between the two soils. He came to the conclusion that if the soil contains less than ·01 per cent. of phosphoric acid soluble in this citric acid solution it was in need of available phosphoric acid to be supplied to it in the form of manure, but if it contained more than ·01 per cent. it did not require an application of available phosphoric acid. By similar reasoning he came to the conclusion—but here his conclusion was not so certain—that if a soil contains less than ·005 per cent. of potash soluble in this citric acid solution it wanted potassic manure supplied to it, but if it did not have less than that quantity it was not in need of potassic manure. This is the process very generally adopted in order to determine available phosphoric acid and available potash.

Turning again to our extraction of soil with strong hydrochloric acid, at the end of the day the liquid is allowed to get cold and is filtered; what remains on the top is carefully washed with distilled water and dried and weighed and is recorded as "insoluble

silicious matter" (non-available material). What goes through the paper filter contains all the potential and available plant food and other soluble constituents of the soil, namely, soluble silica, potash, soda, calcium oxide, magnesia, manganese oxide, iron oxide and alumina, titanium oxide, phosphoric anhydride and sulphuric anhydride. All these are dissolved by the use of this strong hydrochloric acid, they are afterwards separated and estimated and the amounts are recorded as shewn above. There are specimens of these substances on the table which you may afterwards examine. The last item recorded in the upper division of this analysis is "combined water and organic matter, &c." This item records collectively the amounts of combined water, humus, and the small quantities of nitric anhydride, and ammonia and all these are driven off by burning the soil at a red heat in a platinum dish over a gas or other clean flame. The amounts of nitrogen, of humus and of carbonate of lime are recorded in the lower part of the sheet and lastly, as already explained, we extract the soil with one per cent. citric acid solution and estimate the amount of phosphoric anhydride and potash dissolved by it, which, in accordance with the researches of Dr. Bernard Dyer, we record as available phosphoric anhydride and potash.

How Results can be Calculated to the Acre.

Inasmuch as the results of the soil analyses are generally recorded in percentages, it is rather puzzling to planters to calculate what they mean. In order to get over that difficulty, we need simply to consider this—thorough tillage very rarely goes below a depth of nine inches, and therefore, for the purpose of finding out to what depth a plant is likely to feed, we need merely confine ourselves to the depth to which tillage takes place, namely, nine inches. An acre of soil nine inches deep has an approximate weight of 3,000,000 lbs. Now, if I tell you that there is 1 per cent., say, of calcium oxide in that acre of soil, you can easily determine by simple calculation—that if there is one pound in 100 pounds, there must be 30,000 pounds in 3,000,000 pounds. The percentages of the different constituents ascertained by the analysis are recorded in one column and the number of pounds per acre of each constituent are recorded in the adjacent column.

The Law of Minimum.

Another point of great importance may be explained by reference to the above records of soil analyses. You will note that one of the soils contains only ·009 per cent., or 270 pounds per acre of phosphoric anhydride actually available for the next year's crop. That is a very small quantity, and one has little hesitation in saying that such a soil is a poor soil and not fertile for sugar-cane cultivation. When we look at the potash we find it contains only a trace—an amount not estimable—and therefore with regard to potash also, it is a very poor soil. With regard to nitrogen, this soil contains ·272 per cent., or 8,160 pounds, nitrogen per acre—which is almost equal to the amount of nitrogen in 20 tons of sulphate of ammonia.* From this fact you might urge that the presence of so much nitrogen would make up for the deficiency of the other constituents, and you might imagine that the soil would still be fertile. But as a matter of fact it is not the particular constituent of plant food that is in abundance, but the constituent that is deficient that determines the amount of the crop. This, in agriculture, is called the *law of minimum.* Therefore, suppose several constituents are found in abundance in the soil, but one constituent, say potash, is too small for the needs of the crop, that one constituent is sufficient to upset the whole soil. It is the constituent which is in the minimum quantity that you have need to look after. If most of the constituents are present in large amount and one constituent is present in very small quantity, the soil is infertile, and you will have this remedy, that you know there is only one constituent necessary to turn an infertile soil into a fertile soil, and this you can supply in the form of manure.

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* As we shall afterwards learn, this nitrogen contained in the humus is only slowly available as plant food.

LECTURE III.

SOILS AND MANURES IN RELATION TO THE CULTIVATION OF THE SUGAR-CANE.

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In the course of my last lecture I alluded to the important proximate constituents of soils. These constituents are sand, calcium carbonate, clay, and humus. We must now briefly study their more important properties.

Retention of Soluble Plant Food.

I must now allude to the very important subject of the retention of soluble plant food by the soil. There is an experiment upon the table (Fig. 18) in which solutions of nitrate of soda, sulphate of ammonia, super-phosphate of lime, and sulphate of potash have been poured upon soils in cylindrical glass funnels, and the water that has percolated or drained through has been tested. This is similar to rain falling upon soils in which these soluble fertilizers have been applied, the drainage water which passes through being afterwards collected and tested. Now we find that the nitrate of soda and the sulphuric acid (of the sulphate of potash and sulphate of ammonia) pass through, and can be detected in the drainage water, but the ammonia, phosphoric anhydride, and potash cannot there be detected, but are retained by the soil.

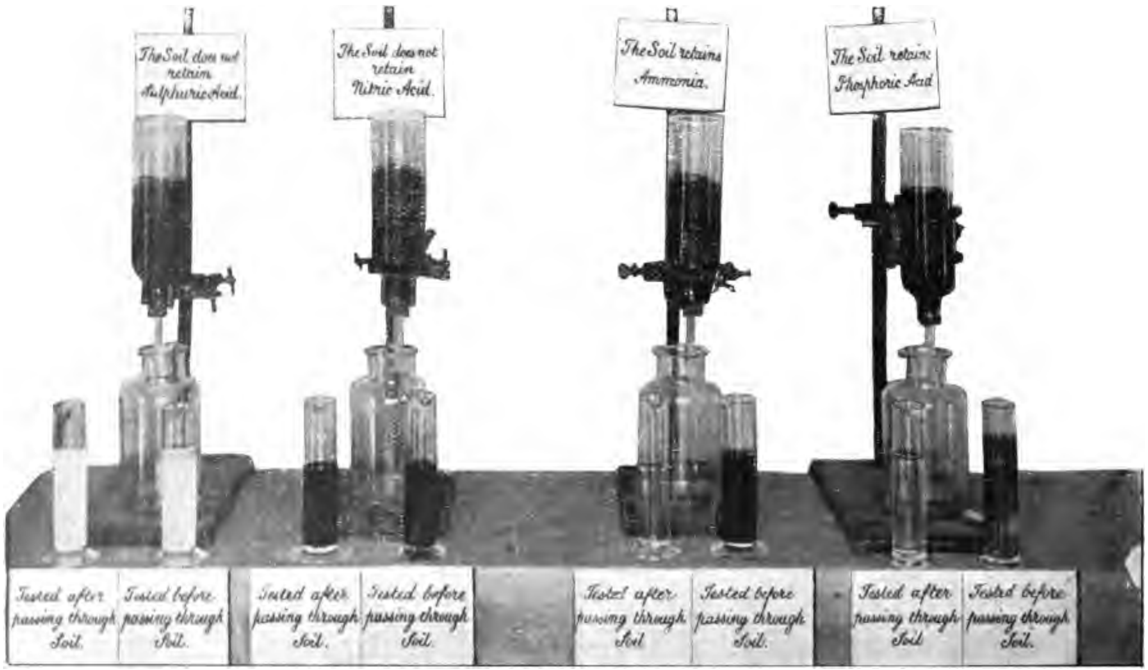

FIG. 18.

Retention of soluble manures by soil. Looking from left to right of the figure—sulphuric acid not retained, nitrate not retained. ammonia retained (difference of colour in the two vessels). phosphoric acid retained (one vessel clear and the other opaque with precipitate).

From this experiment we come to the following conclusions—that nitrate of soda must be applied only when the plant is ready to take it up, otherwise it will pass through the soil in the drainage; but potash salts and soluble (as well as insoluble) phosphates may be safely applied quite early, as soon as the canes are planted, since there is no danger of these substances being washed through the soil. We also learn that sulphate of ammonia, in a climate subject to heavy rains, is less liable to loss by leaching, and may therefore be safely applied in large applications and less frequently than nitrate of soda, which must always be applied at short intervals and in small doses.

The ammonia is retained by the humus which is of acid nature, and to some extent by the clay, the presence of calcium carbonate (chalk) being of great assistance. The phosphoric acid is converted by the calcium carbonate into precipitated phosphate—in which form it is soluble in water impregnated with carbonic anhydride, and in the acid exudation of roots—and is therefore readily available. It may be converted by the iron oxide of the clay into iron phosphate, in which form it is much more insoluble and much less available. The potash is retained chiefly by the clay and to some extent by the humus; here, again, calcium carbonate is of great assistance.

Silicious sand has no power of retaining soluble plant food, hence the importance of a due proportion of clay, chalk, and humus. In manuring light sandy soils all manures must be applied at a time when they can be made use of by the plant. Farmyard manure may be applied to clayey soils long before the crop is planted because its soluble constituents will be retained. Consequently it can be comparatively fresh and will have plenty of time to rot in the soil. In sandy soils, however, the farmyard manure must be applied immediately before planting because soluble plant foods will be washed through unless the plants can soon take them up. In such soils the manure must be well rotted, otherwise what we shall know of hereafter as denitrification will take place when the artificials are applied.

Cohesion.

The cohesion of a given constituent of a soil is the power of the particles of that constituent of adhering or sticking together. You

all know, for example, that sandy soils are loose and easy to work and do not puddle if stirred when wet. You are equally well aware that clay soils are close, sticky, and difficult to work ; if stirred when wet so that the little air between the particles is replaced by water, the particles stick together or cohere strongly and the clay becomes puddled.

Cohesion is a property depending upon the amount of surface. Two flat sheets of glass pressed together cohere strongly, and the larger the surfaces in contact the greater the force necessary to separate them. The surface area exposed by a cubic piece of rock of one inch edge, that is, one cubic inch of rock, is six square inches because there are six faces and each has an area of one square inch. If we pound up this cubic inch of rock until its particles are cubes

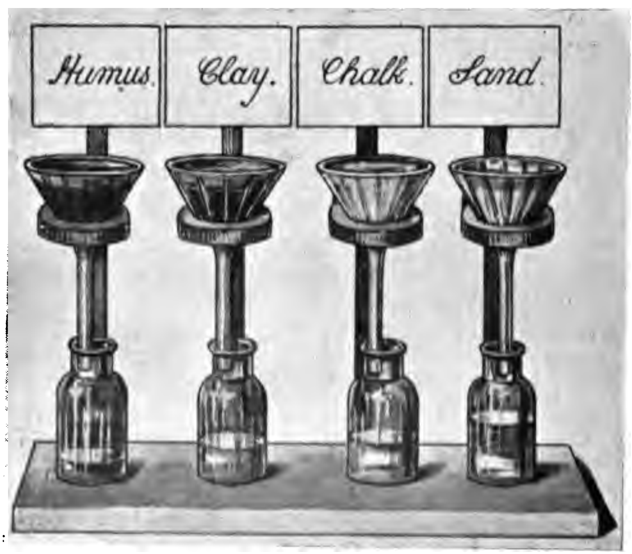

FIG. 19.

Permeability and retention of water.

The relative heights of water in the bottles beneath the funnels indicate the amount that has been retained by the different soil constituents in the funnels.

of 0·5 millimetre edge, that is the size of coarse to medium sand, there would be 125,000 particles and the total area of surface of all these particles would be 300 square inches. If we further pounded these particles until they were cubes of ·002 millimetre edge, that is somewhere about the average size of agricultural clay particles, there would be about two million million of these particles with a total area of surface of about 76,000 square inches. This will serve to show the rapid increase in the number of particles and of surface area in passing from sand to clay. Humus is an important constituent of soils in relation to cohesion since it helps to bind loose sandy soils and to open stiff clay soils.

PERMEABILITY.

To illustrate the permeability of these different soil constituents, I have before me (Fig. 19) four glass funnels of which the tubes are loosely plugged with glass wool, and in which have been placed equal weights of sand, calcium carbonate, clay, and humus. Water is poured upon each of these funnels. It rapidly penetrates the sand and runs through ; it much more slowly runs into the chalk and drains from it ; it penetrates the clay with exceeding slowness and takes many hours to drain away ; it rapidly penetrates and runs through the humus. Sand is very open and permeable ; chalk is much less so ; clay is highly impermeable ; humus though close is very permeable.

RETENTIVENESS.

If after the water has drained through we weigh the funnels we shall find that the sand retains one quarter of its weight of water, the chalk one-half of its weight, the clay three-quarters of its weight, and the humus one and a half times its weight. Therefore the sand has low retentive power for water, the chalk moderate retentive power, the clay high retentive power, and the humus very high retentive power, a property which is exceedingly important in relation to the storage of water in soils.

As we have seen, soils rich in clay and humus retain much moisture. Of all substances, weight for weight, water takes the greatest quantity of heat to warm it : consequently soils rich in

clay and humus have a great capacity for heat: hence clay soils are cold, but soils rich in humus, being dark in colour, readily absorb the direct heat of the sun and so in a measure are warmer.

THE ASCENT OF WATER IN SOILS—CAPILLARITY.

I now come to an important physical phenomenon known as capillarity. It is the power possessed by liquids of rising in tubes whose bore is so narrow as to be comparable in size to a hair. I have before me (Fig. 20) four glass tubes of different internal

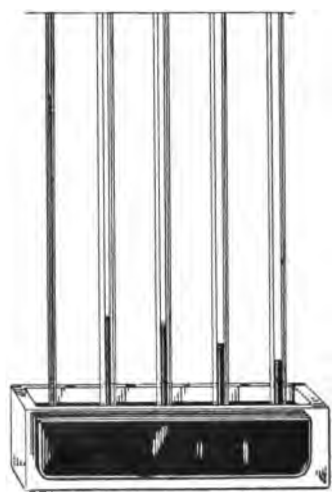

FIG. 20.

Capillary tubes standing in coloured water, showing that the narrower the tube the greater is the rise of water.

diameters or bore. They are standing in water coloured red in order that it may be visible to you. You see that the water has risen in each but to different heights. In the largest tube it has scarcely risen at all, in the smallest it has risen about six inches and in the intermediate tubes to an intermediate height. In a

tube of which the internal diameter or bore was $\frac{1}{500}$th of an inch the water would rise to a height of two feet. Now the water will rise to the same height whether the tube be straight or bent or

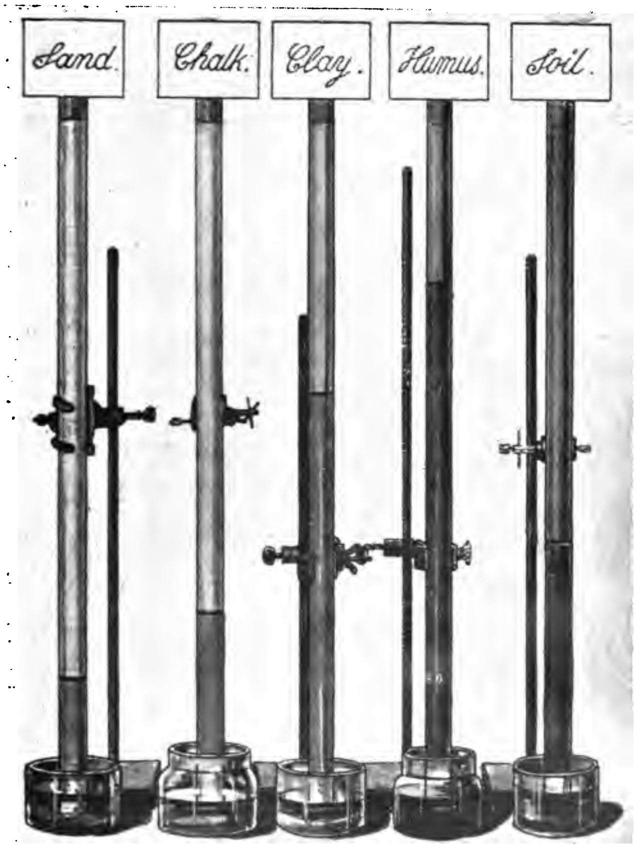

FIG. 21.

Glass tubes filled with different soil constituents and standing in vessels of water. The marks shew the height the water has risen in sand, chalk, clay, humus and soil.

branched: and we may compare the spaces amongst the particles of a soil to so many branched irregular capillary tubes, the internal diameter of which will vary, and will depend upon the size of the particles and the closeness with which they are packed. Thus we find (Fig. 21) taking the constituents of soils one by one that the particles of sand being comparatively large and often angular, the capillary spaces or interstices are large; and while in a stratum of sand water rises rapidly it will not rise much higher than 10 inches. In clay both the particles and the interstices are extremely small and water rises slowly but to a height of 30–40 inches. Humus is so constituted that while both the particles and interstices are fine, water rises rapidly and reaches a height of 60 inches.

Effect of Tillage on Capillarity.

When a soil is tilled or cultivated, it is loosened, the particles are separated from one another and the capillary interstices are broken up: the capillarity is destroyed until the soil is again more or less consolidated.

Sandy soils being so much more permeable to both water and air do not require the same amount of tillage as clay soils and after tillage may actually require consolidation by rolling.

Agricultural Classification of Soils.

Now you will have gathered from the foregoing that the proportions of sand, chalk, clay and humus are of the greatest importance in determining the chemical and physical characters of a soil. This the planter has so far recognised as to name soils according to the proportions of each of these constituents. Thus a soil containing less than 10 per cent. clay is a sandy soil, 20–30 per cent. of clay a loamy soil, 50 per cent. of clay and upwards a clayey soil. A soil that contains 5-20 per cent. calcium carbonate is a marly soil, and one containing 20 per cent. and upwards is a calcareous soil. Such is the importance attached by the farmers of all countries to the value of humus that a soil is actually called poor or rich according to the quantity present of this constituent. A soil containing 1½ per cent. or less of humus

is a poor soil, more than 1½ up to 3 per cent. humus an intermediate soil, 3–5 per cent. humus a rich soil, and 5 per cent. upwards a very rich vegetable soil. A soil containing 30 per cent. clay, 6 per cent. calcium carbonate, and 2 per cent. humus (proportions frequently present in Barbados soils) would be an intermediate marly, loamy soil. Thus the agricultural names given to different soils are based partly upon the size of the particles as determined by mechanical analysis and partly upon the chemical nature of the soil.

THE BIOLOGY OF SOILS.

Having now, I hope, conveyed to you some idea of the chemical and physical properties of soils, I shall turn to another part of my subject of great interest and importance, I mean the biology of soils or the study of life occurring in soils.

The most important forms of life occurring in soils are earthworms and bacteria.

EARTHWORMS.

The food of earthworms is humus ; to obtain this they have to swallow large quantities of earth which they obtain from the subsoil and which generally contains only one per cent. or less of humus. This earth while passing through their alimentary canal is subjected to the action of their digestive juices which dissolve out the humus and render the mineral particles more soluble to the carbonic anhydride water of the soil and the acid exudations of root hairs ; it is then excreted at the surface of the soil as worm casts. In burrowing their way through the soil they leave passages extending right down to the subsoil, and into these air can penetrate. Thus, these animals assist in converting subsoil into fertile soil and bring it to the surface adding to the depth of the soil proper. Darwin has estimated that in this manner ten tons of dry earth per acre per annum pass through the bodies of earthworms and is brought to the surface.

NITRIFICATION.

The presence of bacteria in the soil is of paramount importance because they are the agents which elaborate calcium nitrate, a form

in which all plants take up and assimilate nitrogen. Nitrogen is the most expensive of plant foods; it is also essential to the existence of life. Protoplasm is the material that constitutes the living part of all tissues, and nitrogen is an indispensable constituent of protoplasm. If we kill protoplasm and analyse it in the form of albuminoids, it will be found to contain about 16 per cent. of nitrogen.

Now the great store of soil nitrogen exists in the form of humus; and the question is, how is the nitrogen of humus which is insoluble in water and not available for the use of plants converted into calcium nitrate?

The answer is supplied by the following:—In the soil live certain organisms, mere microscopic specks of protoplasm or living matter; they are called bacteria, and they are endowed with remarkable powers. And just as amongst civilised communities it has been found advantageous to train some men as carpenters, others as masons, others as plumbers, and so forth, so nature has found it of advantage that different sets of the bacterial workmen should be trained so that one can perform one kind of work and another another kind. In the soil one kind of bacteria lives on humus, and by the aid of oxygen (a constituent of the atmosphere) converts the nitrogen of the humus into ammonia and the carbon into carbonic anhydride. The ammonia is then handed over to another set of bacteria, and these, by the aid of oxygen and calcium carbonate, convert it into calcium nitrite; this calcium nitrite is then taken in hand by a third set of bacteria that with the aid of oxygen convert it into calcium nitrate which is soluble in water and is a form in which the plant is able to utilise nitrogen.

You will observe that oxygen and calcium carbonate must be present if the bacteria are to perform their work. A favourable temperature or degree of heat (98° F. is the most favourable) and the presence of moisture are also necessary. The oxygen is provided by the air admitted by tillage and drainage into the interstices of the soil; moisture is derived directly from the rainfall or from the water reservoir in the soil; calcium carbonate (carbonate of lime, chalk, limestone) is a constituent of all fertile soils; the favourable temperature occurs in temperate and subtropical climates during summer, it occurs—but not the favourable supply of moisture—in the tropics all the year round.

It should be our object in Barbados to produce such a condition of soil during the months of active growth, that is from June in one year to January of the next, as will ensure a maximum of nitrification during this period when nitrogenous plant food is most required. It is during these months that we shall find it of advantage to supplement what is supplied by the soil itself by the addition of nitrogen as a top dressing, either in the form of the readily soluble and immediately available nitrate of soda, or in that of readily soluble and rapidly, but not immediately, available sulphate of ammonia.

You will also observe that in the oxidation or decomposition of the humus, as the result of the activity of these bacteria, carbonic anhydride gas is abundantly produced and is dissolved up by the moisture adhering to the particles of soil; this moisture, thus impregnated with carbonic anhydride, acts powerfully, as you will remember, as a disintegrating agent of soil or rock particles, converting potential plant food into soluble and available plant food. Thus the activity of these nitrifying bacteria is constantly leading to the production of both nitrogenous and mineral plant food from the materials stored up in the soil.

We cannot help being struck by the fact that nature has been most economical in its arrangements for the preservation and supply of nitrogenous plant food. If the nitrogen of soils existed entirely as nitrate, the rain would rapidly wash it all away; did it exist as ammonia, nitrification would speedily convert it into nitrate with a similar result; but existing stored up in humus, an insoluble form, a form that is only converted into nitrate under conditions of warmth and moisture which are at their best when plant growth is most active you have the production of available nitrogen at the very time when the plant most wants it.

Farmyard Manure.

Farmyard manure is a mixture of urine and decomposing vegetable matter such as litter and the undigested remains of food. If kept moist and well aerated and supplied with a sufficiency but not an excess of earth in which calcium carbonate is a constituent, you have all the conditions for active nitrification, that is, for the conversion of the nitrogen of the vegetable matter and urine into ammonia and into calcium nitrate, for the multiplication of the

bacteria, and, I may add, for the elaboration of the potential plant food in the added earth. When treated in this way the farmyard manure heap becomes not only a factory of ammonium salts and nitrate, but also a nursery for the raising of multitudes of bacteria from those sown in the heap in moulding. The precautions to be observed in the management of this heap are, first, to avoid too high a temperature which may expel and cause the loss of ammonia formed by the fermentation of the urine and of the vegetable matter; the heat produced can be kept under control by watering the heap when necessary. The second precaution is to build the heap in a covered place so that it is not exposed to the rain which in washing through would carry away soluble salts of nitrogen and potash. There is no doubt, by the judicious use of mould and water, that all the valuable constituents of farmyard manure can be retained in the manure and nitrifying bacteria multiplied, and such farmyard manure will not only render land fertile in consequence of the available plant food that it brings, but will supply bacteria to land deficient in these agents of nitrification.

Land may be infertile from many causes. Want of drainage or tillage, the presence of injurious substances such as ferrous (iron) salts, excess of alkaline carbonates or of common salt, the absence of a sufficient supply of one element of plant food, may any of them reduce an otherwise highly fertile soil to infertility; and to all these may be added a further cause of infertility and that is the absence of the bacteria of nitrification. This last want would be supplied by the application of farmyard manure made up as above. Recourse is sometimes had to the application of gypsum which fixes the ammonia as ammonium sulphate. Dilute sulphuric and other acids (such as phosphoric acid as superphosphate) are similarly used to combine with the ammonia from the urine and vegetable matter. This arrests nitrification in the ammonia stage; the practical value of this method in comparison with the one first referred to has still to be worked out.

DENITRIFICATION.

Amongst the communities of bacteria that have their dwelling in the soil is one whose members are able to produce a change very different from those we have just studied. They are called denitrifying bacteria because they take nitrates and ammonium salts

and set free the nitrogen, rendering it useless as plant food. These denitrifying bacteria only work in the absence of oxygen—a condition existing in water-logged soils—in soils rich in humus but not aerated by tillage, or in a pen manure heap not sufficiently aerated, where you have decaying vegetable matter that rapidly uses up the oxygen. Instances have been observed where less crop has been obtained on plots receiving farmyard manure than on unmanured plots, because the farmyard manure, ill-rotted and infested with these denitrifying bacteria, caused the destruction of the nitrates formed by nitrification in the soil. And again there is always a danger that the application of nitrate of soda and sulphate of ammonia on the top of freshly dunged soil may be wasted owing to denitrification. The addition of phosphates and potash increase the activity of denitrifying bacteria in farmyard manure, because they supply food to the bacteria.

Artificial manures should therefore not be applied at the same time or too soon after the application of farmyard manure.

Leguminosæ and Soil Bacteria.

A fitting conclusion to the study of nitrification is an account of those bacteria which, living in partnership with the Leguminosæ utilise free atmospheric nitrogen and build it up into compounds of nitrogen for the use of their partners. You are all well acquainted with that order of plants that produces their seeds in pods or legumes.

Examples are abundant around us in peas and beans, the *Barbados Pride*, the Flamboyant and the like. If the rootlets of these Leguminosæ be examined under favourable circumstances, you will see swellings, nodules or tubercles upon them, varying in size from a pin's head to a small lime ; there are examples on the table (Fig. 22) of large root nodules on the root of a *Velvet bean* grown at Sandy Lane.

On examining thin slices of these nodules under the microscope, you will see the swollen tissues of the root crowded with large numbers of bacteria. These bacteria are present in all fertile soils and when young Leguminosæ are beginning life, they make their way to the root hairs, enter them and travel into the root, stimulate the cells to greatly increased growth while the bacteria

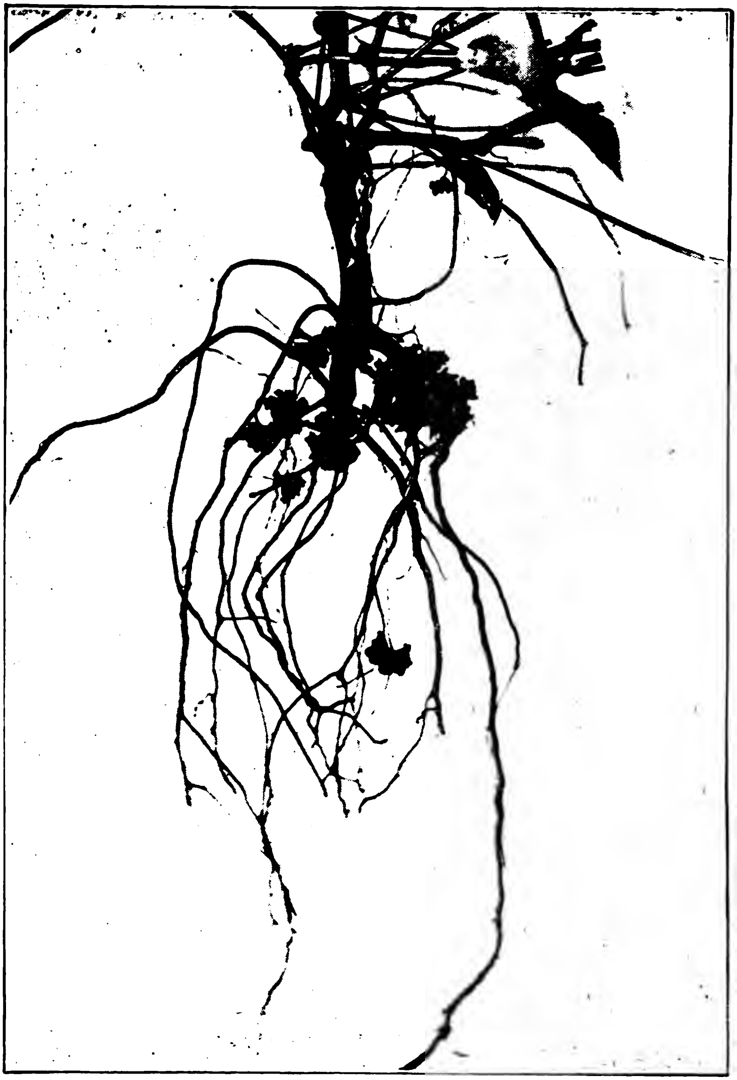

FIG. 22.

Nodules on the roots of a leguminous plant. (Velvet bean.)

themselves rapidly multiply. The air in the interstices of all well drained and well tilled soils supplies the nitrogen which these bacteria take in and build up into nitrogenous compounds ; they store up these compounds in their protoplasm, but finally hand them over to the leguminous plant, which all along has been fulfilling its share of the partnership by supplying the bacteria with carbohydrates and mineral food.

NITRAGIN.

Now even the bacteria that assimilate atmospheric nitrogen are not all of one kind, and it has been found that for each leguminous plant there is a special nitrogen bacterium. A factory has actually been founded in Germany for the purpose of preparing pure cultures of bacteria suitable for different leguminous plants. These pure cultures are sold under the name of nitragin and it is stated that by using its appropriate *nitragin*, leguminous plants will produce root nodules and assimilate nitrogen in soils in which they would otherwise be unable to do so, owing to the absence of their appropriate bacterium. Experiments have not up to the present, however, confirmed this statement.

LEGUMINOUS GREEN DRESSING.

Leguminous plants can grow in soils absolutely devoid of nitrogen provided the right kind of bacteria be present ; in these circumstances and in the manner indicated they will store up large quantities of nitrogen. In an experiment last year at Waterford plantation it was found that the Bengal bean actually stored up 120 pounds of nitrogen per acre. It is probable that a large proportion of this nitrogen was elaborated by the nodule bacteria from the atmosphere, and if this crop were turned in as a green dressing or fed to the cattle and the manure carefully preserved, there would be an addition to the estate of nitrogenous plant food to the value of, say, $8.00 per acre, which is a handsome profit on the cost of the seed and labour.

A precaution is to be noted in the growth of such luxurious leguminous vines in Barbados. The soils in this island are in very many places thin, and their water storage capacity correspondingly

limited. Leguminous plants possessing a luxuriant leaf growth like the Bengal bean give off a large quantity of moisture which they obtain from the soil, they should therefore be sown in time to reap or turn in in September so that an ample proportion of the rainy season is left to accumulate a store of moisture for the "spring" and growth of the young cane crop to be planted in the following December.

The Soil as a Storehouse of Water.

I turn now to the soil as a *reservoir* or *storehouse of water.* Let us picture to ourselves an ideal instance of a well-drained well-tilled soil. Passing from the surface downwards we first have (Fig. 23)

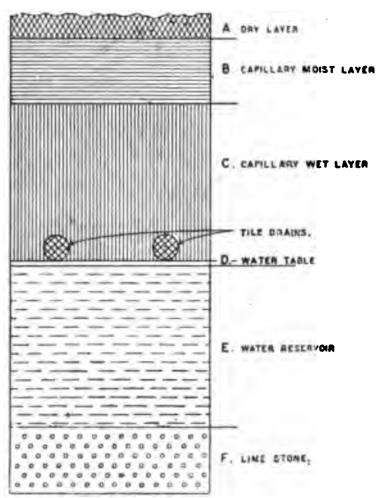

Fig. 23.

Diagram illustrating the distribution of water in the soil.

one or two inches of dry powdery loose surface soil in which the capillary tubes are broken up and through which water as such cannot rise to the surface. Under this is a layer of soil (B) some

six or more inches deep, loose enough to allow the free admission of air, but sufficiently consolidated to retain a due measure of capillarity ; this depth is quite moist, but not wet, and its moisture which clings to the surface of its particles and particularly to the humus is obtained from the next layer (C) which is more consolidated, in which capillary power is marked and which is wet by the water that has risen in its capillary tubes from the reservoir beneath. The lower limit of C is marked by the water table (D), a level below which the subsoil is completely water-logged ; if a hole be dug in the soil to extend below D, a pool of water will rapidly form to the level of D but no higher because it can rise no farther except in capillary tubes. It is the subsoil (E) beneath the water table that forms the water reservoir or storehouse of the reserve supply from which by capillarity the layers above obtain their water. It is in the two upper layers A and B that nitrification will be most active, but there will also be some root growth in C. There will be no root growth below the water table D.

DRAINAGE.

Soil can only be tilled above the level of the water table D, and the object of drainage is to lower the water table D and increase the depth of tillage soil in which air can penetrate, nitrification and elaboration of available plant food can take place, and in which plant roots can grow and utilise that food. But in lowering the water table and deepening the layer of tillable soil, two precautions must be carefully observed : the first is that the depth of the water table is not lowered beyond the limit from which water can rise by capillarity through the layers above for the use of the surface soil, and the second is that we leave sufficient depth of reservoir to store all the water we require for periods of drought. The second precaution will be especially necessary in the limestone soils of Barbados, where immediately beneath the water reservoir lies a layer of porous limestone of great depth ; all water that reaches this limestone is rapidly drained away to a depth whence no capillarity can bring it back, and the lesson for us in Barbados is to be careful that in tilling and draining too deeply we do not lose our reserve of water. Our planters have been greatly interested by recent accounts of what is done in Hawaii, but our conditions are quite different from those in that island where the soil is very rich, deep, friable, and pulverulent, rendering it easy to till to great

depths, and where the unlimited supply of pumped irrigation water dispenses with our reservoir within reach by capillarity. In their deep, rich, and well-watered soils a luxuriant root system can flourish, resulting in the production of phenomenal crops of cane and sugar.

TILLAGE.

The implements of tillage are of three kinds. (1) The fork or plough breaks up the soil to a certain depth, pulverizes it, and turns it completely over, exposing the lower particles thus brought to the surface for a whole season to the atmosphere. They are for surface soil the most thorough implements of aeration and disintegration.

(2) The subsoiler, which in many countries is worked at the bottom of the plough furrows, opens and disintegrates the subsoil without turning it over or bringing it to the surface. The object of this is well known ; the subsoil is neither as rich in plant food nor bacteria as the surface soil, and hence, while we are glad for the cane plant to utilise the subsoil in addition to the surface soil, we prefer to keep the former below. By the judicious use in loamy soil of the subsoiler, the depth of soil available to plant roots can be increased and the root system enlarged—the so-called surface-feeder discovering a faculty of developing deep roots not before thought of—in this way a greater depth and volume of earth is tapped for plant food and water, and a larger crop can be supported above ground.

(3) The cultivator, an implement with many tines or teeth, simply pulverizes a few inches of the surface soil without turning it over ; it breaks up the capillary tubes formed by consolidation, and in dry weather prevents water getting, by capillarity, to the surface to be lost by evaporation. It aerates the surface layer and promotes nitrification. It tears up weeds until in January or February we can spread trash upon the fields and so dispense with further labour.

TRASHING.

Trash protects this powdery surface from the consolidation caused by showers of rain falling directly upon the earth and by the tread of labourers ; in this way, as well as by its direct

covering, it prevents loss of moisture and enables roots to grow to the very surface, since they are no longer broken by tillage; it protects these rootlets from the hot rays of the sun; it saves the cost of weeding, for it prevents weeds from growing.

Effects of Drainage and Tillage.

In a well drained, well tilled soil the depth of earth in which roots can grow is increased to a maximum, and this is done without taking water beyond the reach of the increased root system. The rainfall passes *through* such an open soil and not over it, "*wash*" is prevented and water conserved. Air follows this water as it drains through the soil to fill up the interspaces left, and this air brings the oxygen necessary for nitrification and for the elaboration of mineral plant food, as well as nitrogen for the bacteria of the leguminous root nodules. A well-drained well-tilled soil is warm and dry, yet with an accessible reserve of moisture; it is less covered by mists; crops ripen earlier on it; tillage can be carried on later into wet weather and earlier at the end of the wet weather. Such land is healthier for man and beast and plant.

In relation to the importance of tillage the experienced planter will not fail to recollect that some plants require a closer more consolidated soil than others, and that very light soils may actually require to be rolled after tillage to reduce them to a state of consolidation favourable to the growth of crops.

LECTURE IV.

SOILS AND MANURES IN RELATION TO THE CULTIVATION OF THE SUGAR-CANE.

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Tillage and drainage, irrigation, claying, liming, dunging, the application of artificial manures and the rotation of crops are all means whereby we improve or maintain the fertility of soils. I have dealt briefly in the preceding lecture with the effects of tillage and drainage and if the time at my disposal permitted, it would be both interesting and instructive to compare the system of surface drainage in vogue in Barbados with tile and other methods of under drainage practised with so much advantage in some countries. It would also be interesting and instructive to discuss the advantage and cost of irrigation either by utilising large volumes of surface water—which do not exist in this island—or by pumping water from under-ground sources. I can only allude to these parts of the subject in passing. We have constantly to bear in mind that the object of the planter is to manipulate his soil in such a manner as to secure the maximum crop consistent with the maximum profit. Any method of working which, though increasing the crop, does so at an expense greater than the value of this crop-increase, simply leads to loss of money and must therefore be avoided. The subjects of tillage, drainage, irrigation and manuring are bound up with prices, and the successful

practical planter will regulate the expenses he incurs on the management of his land in relation to the state of the market. I cannot to-day do more than briefly allude to this part of the subject.

The Amelioration or Improvement of Soils.

Our previous studies of the chemistry and formation of the soil, of the physical properties of its chief constituents, of the biology or history of the different forms of life occurring in soil, will all help us to grasp the agricultural importance of tillage and drainage and of the other means of maintaining the fertility of, and of effecting the improvement of soils which we have to consider to-day.

Liming.

We are all aware of the difficulty of tilling and draining clay soil and we have seen that the difficulty is due to the large surface exposed by so many minute particles of clay. If by any means we can cause those excessively small particles to congregate together in loose masses or flocks, that is to flocculate, we shall improve the agricultural condition of that land.

In these two glass vessels (Fig. 24) you see water rendered turbid and opaque by the clay which has remained suspended in it for some hours and which would only partially settle if I left it for some weeks. These particles of clay remain suspended because of their extreme fineness. To one of these vessels I now add some milk of lime, that is some slaked lime stirred up in water : you see how rapidly the clay particles sink, while in the second vessel that has received no lime they remain suspended. This experiment shews you that lime causes the clay particles to run together into loose masses, to flocculate, and these loose aggregates rapidly settle in the water. The same flocculation is effected when lime is applied to clay soils ; by this means they are rendered easier to till and both in their drainage and æration are improved—an improvement which our previous studies have shewn us will affect in a beneficial manner all the changes by which the land is rendered fertile to plants.

The application of lime, however, has not only a beneficial physical effect, but also a beneficial chemical effect upon the soil.

Calcium oxide,—which, as we have learned, is another name for lime—is an essential constituent of plant food ; soils deficient in lime (and clay soils are not by any means necessarily deficient in lime) are therefore enriched in one constituent of plant food by its application. Then again we have seen that the presence of calcium carbonate (*i.e.* carbonate of lime) is necessary in the processes of nitrification : the absence of lime in a soil will therefore interfere with the preparation of assimilable nitrogen for the plant, and prejudicially affect the assimilation or taking up of nitrogen. The remedy for this is the application of lime.

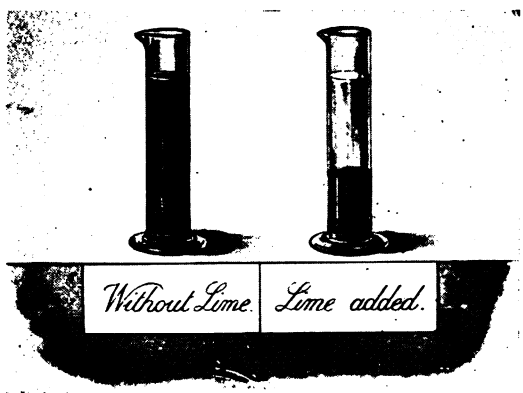

FIG. 24.
Owing to the addition of milk of lime the clay has settled in the right hand vessel and left the water clear.

Lime when applied in the form of quick lime and to a lesser extent in the form of water-slaked lime, hastens the decomposition of humus not only by influencing the activity of nitrification, but also by direct chemical action upon the humus. If therefore applied in excessive quantity to land already not too rich in humus it may lead at first to a considerable increase in crop, followed by a condition of soil-exhaustion due to the excessive destruction of humus : thus an excessive application to such land must be avoided. In both these forms lime acts directly upon the clay, decomposing it and rendering a proportion of potash and some other constituents of plant food available for the use of the crops.

Lime for the purposes that we are now considering, may be applied in various forms. What are their relative agricultural values, and what are their relations to one another?

Limestone, chalk, calcareous sand, all consist of calcium carbonate or *carbonate of lime*, that is a compound of

Calcium Oxide (lime) and Carbonic Anhydride.

When these forms are burned in lime kilns we drive off the carbonic anhydride and get *quick lime* or, "*white lime*," or "*burnt lime*," which is simply

Calcium Oxide.

When quick lime is mixed with water, heat is given out and we get *slaked lime* which is a compound of

Calcium Oxide (lime) and water.

When either *quick lime* or *slaked lime* is exposed to the air or mixed with earth it combines gradually with the carbonic anhydride found in air and in the soil, and forms *calcium carbonate*, that is a compound of

Calcium Oxide (lime) and Carbonic Anhydride.

Marly and *calcareous* soils are soils more or less rich in calcium carbonate.

When an abundant supply of chalk, calcareous sand, or marl is near at hand, these may afford a very cheap means of liming the land; but quick lime and slaked lime are the most effective forms in which to apply lime to land; and, in my opinion, water-slaked lime, which is a fine powder, on account of the ease with which it may be uniformly applied, is the best form for such agricultural purposes. It is usually employed to the extent of ½ ton and upwards per acre.

FARMYARD MANURE.

We come now to the dunging of soil, that is the application of farmyard manure. The consideration of this important waste

product of the plantation will conveniently precede the consideration of the general manurial requirements of the sugar-cane.

I have already dealt at some length with the changes that take place during the saving of this manure, and I have pointed out the means of preserving its most valuable constituents ; I have also pointed out its value as a nursery for the bacteria of nitrification.

I now draw your attention to an analysis of farmyard manure such as is made and used in Barbados :—

RESULTS OF FARMYARD MANURE ANALYSIS.

——	Per cent.	Pounds contained in 40 tons.
Moisture	24·48	—
*Organic matters, &c.	20·43	18,200
Insoluble silicious matters	20·71	—
§Phosphoric anhydride...	·29	260
†Alkaline salts, lime, magnesia, &c.	34·09	—
Total	100·00	—
*Containing nitrogen	·41	367
Equal to ammonia	·49	—
§Equal to tricalcic phosphate...	·63	567
†Containing potash	·38	340
Equal to sulphate of potash	·71	—

THE SUPPLY AND CONSUMPTION OF HUMUS.

The second column gives the number of pounds of certain constituents contained by 40 tons of farmyard manure, which is a not unusual application per acre in well-manured Barbados fields.

When applied to the land it should be as evenly and equally applied as circumstances will permit. You will note that 40 tons contains about 18,000 pounds of organic matter, that is of humus forming material, which gradually becomes changed into humus. In that process it loses weight, so that the humus produced by this 18,000 pounds organic matter is very much less than 18,000 pounds.

Now we have already seen that humus is being constantly used up in the process of nitrification. This consumption of humus is an essential part of the activity of soils, and is a necessary accompaniment of fertility. There is thus a constant loss of humus. A due proportion of humus, however, is absolutely essential if our land is to remain in good heart; it is necessary for its valuable properties in relation to the movements and conservation of moisture, it is necessary for its retention of ammonia, it is necessary in nitrification. Since in cultivated soils it is being constantly consumed, how is it replaced? The answer is by the application of farmyard manure, of green dressings, trash, plant roots, and compost (that is, leaves, branches, and other organic waste material of the plantation). In fact, we can compile a blank form in which the losses and gains in humus are thrown into a " Humus account " such as the one I am now pointing to.

HUMUS ACCOUNT.

Dr.		*Cr.*	
1. To balance carried over from last a/c.	—	1. By available plant food a/c for humus consumed in nitrification.	—
2. " Farmyard manure ...	—		
3. " Leguminous green-dressing.	—		
4. " Plant roots	—		
	—		—

Upon reference to records of analyses of soils you will see that good Barbados soils contain two to three per cent. humus, that is 60,000 to 90,000 pounds per acre. On many soils 40 tons of farmyard manure—containing *when made without any excessive quantity of*

mould, say 18,000 pounds of organic matter—is applied every two years, yet no marked increase—if any—occurs in the percentage of humus in such soils ; it is therefore evident that the destruction of humus in this climate is exceedingly rapid. If by neglecting to apply sufficient farmyard manure to a field its humus is diminished say by one per cent. (equal to 30,000 pounds per acre), it will be easily seen from what I have said how difficult it will be in the presence of this constant destruction of humus to bring the percentage up again, to restore the land to good heart. These considerations will serve to confirm the opinion already held by every competent planter in Barbados of the importance of preserving every particle of trash and other organic waste material unless other considerations render it impossible to do so.

The Effects of Farmyard Manure are Lasting.

The analysis of farmyard manure before you indicates that 40 tons of this excellent sample contains 260 pounds phosphoric anhydride (that is phosphoric acid) ; multiply this by 2·18 and you obtain its equivalent, 567 pounds of tricalcic phosphate ; it also contains 340 pounds of potash. Now, I find that the greater proportion of both these constituents are soluble in ammonic citrate and also in citric acid, in other words, they are immediately available to the roots of any plant that can reach them. You also notice that this 40 tons of manure contains 367 pounds of nitrogen ; about half of this is in a readily available form for the present crop, the other half is only slowly available for future crops. In other words, both in regard to the physical condition of the soil and in regard to its manurial value as a nitrogen supplier, the effects of an application of farmyard manure are seen not only in the year of application, but also in succeeding years ; therefore the application of farmyard manure is a source of lasting improvement to the fertility of the soil.

Farmyard Manure is a Return to the Land of Waste Material.

If you compare the above application of 367 pounds of nitrogen, 567 pounds of phosphate, 340 pounds of potash, with the amounts contained in a liberal application of artificial manure, you will at once

contend that the former is a very large application of these constituents of plant food, and you will be inclined to think that our usual and comparatively small application in artificial fertilizers should have very little comparative effect. There is no doubt that the application of farmyard manure is a very important part of our Barbados system ; but as I shall soon point out, this farmyard manure is really only a return to the land of a portion of what has been removed in previous crops.

Leguminous Green-Dressing and Humus.

In our experiments last year upon leguminous plants, we found that the Bengal bean gave the largest yield ; and besides the 120 pounds of nitrogen per acre already alluded to, it contained 3,960 pounds per acre of organic matter, that is, of humus forming material. Although this amount of organic matter is small compared with that in the farmyard manure, you will all see, whether turned direct under the land or fed to your cattle to increase the farmyard manure, that it is an important source both of nitrogen and of humus.

Artificial Manures. What are the Essential Constituents of Plant Food?—Water Culture.

I now turn to the use of artificial fertilizers in the cultivation of the sugar cane.

In our study of the composition of soil we saw that it contained a large number of different substances, some in large and others in small quantities, so the first question I will propound is, "*What constituents of soil are essential plant food to the sugar-cane?*" This question has been conclusively answered by experiments conducted by the well-known method of water culture.

If a cane top, such as we use for planting purposes, be immersed in a vessel of pure distilled water, it will form roots and leaves, and if exposed to light, will grow for a short time ; at the end of that period it will droop and die, and it dies because there is no plant food in the water—pure distilled water being devoid of nitrogen or any mineral constituent of plant food.

If, however, we repeat the experiment, but in this case use distilled water to which are added compounds of silica, potash, soda, lime, magnesia, iron, manganese, phosphoric acid, sulphuric acid, and nitrogen, then we shall find that the cane grows perfectly well. If in a third experiment we grow the cane in a vessel of distilled water to which have been added all the above constituents except a compound of nitrogen, the plant after a time turns a sickly yellow and dies. If in another vessel everything is present except phosphoric acid, the cane plant in that vessel will similarly die after a short period of growth. In like manner—by repeating the experiment with several vessels of distilled water, and in each vessel putting all the constituents except one, the constituent omitted being different in the case of each vessel—it has been conclusively shown that potash, lime, magnesia, iron, phosphoric anhydride, sulphuric anhydride, and nitrogen are essential constituents of plant food for the sugar-cane, and experiments of this nature have been carried out by Dr. Went in Java. It may also be concluded that the presence of silica is beneficial for its mechanical effect in stiffening the tissues of the cane-stalk.

Now, if we again glance at an analysis of one of our soils, we shall see that silica, iron, magnesia, and generally lime are present in quantities that are practically inexhaustible.

Nitrogen, Phosphate and Potash.

Nitrogen, phosphoric anhydride, and potash are present, however, in quite small quantities, and there will be no difficulty in arriving at the conclusion that in most ordinary cultivable soils these are the constituents that are generally lacking. Experiments confirm this conclusion.

The method of water culture will not tell us how much nitrogen, phosphoric anhydride, or potash to apply to canes growing in a given soil in order to produce the maximum crop ; to get this information we must employ other means.

The Analysis of the Cane.

What help will the analysis of the cane itself afford us? The following results are extracted from the publications of Professor

Stubbs of Louisiana, of Professor Maxwell of Hawaii, and from the Dodds Reports.

The purple cane removed from the soil in

—	Pounds of			
	Nitrogen.	Phosphoric anhydride.	Potash.	Total mineral matter.
Louisiana, per ton of cane ...	1·08	1·04	1·22	11·2
„ per 20 tons of cane	21·6	20·8	24·4	224·
Hawaii, per ton of cane ...	2·82	1·3	6·8	18·1
„ per 20 tons of cane ...	56·4	26·	136·	362·

The average of the determinations of several years shew that the Bourbon cane removed from the soil in

—	Pounds of		
	Nitrogen.	Phosphoric anhydride.	Potash.
Barbados, per ton of cane	1·68	1·3	2·28
„ per 20 tons of cane ...	33·6	26·	45·6

These results show considerable differences one from the other, and they are doubtless in great measure due to differences in the composition of the different soils. If we judged from the analyses of the cane grown in the rich Hawaiian soil, we should conclude that large applications of nitrogen and potash manures were necessary; if we judged from the cane grown in the soils of Louisiana, we should conclude that much smaller applications were necessary; and if we looked at the Barbados results (which, being

obtained with another variety of cane, are not strictly comparable with the Louisiana and Hawaiian canes) we should see that they point to a conclusion different from either of the two former.

In other words, plants, like animals, consume food extravagantly or economically according to the supply. A plant grown in a virgin soil, as extraordinarily rich in plant food as some of those in Hawaii, will be extravagant in the amount it takes up compared with similar plants grown in a poorer soil ; but it does not at all follow that the large amount of food taken up by the plant is necessary to produce the maximum crop, and indeed, a careful study of the question will soon lead to the conclusion that the analysis of the plant—which even takes up compounds of soda, titanium, manganese, substances that we believe are not necessary at all—will not tell us how to manure our cane fields.

A conspicuous example may be quoted from English agriculture in support of this conclusion ; it is the well-known comparison of the turnip and wheat in relation to the supply of phosphoric anhydride. Turnips take up little phosphoric anhydride compared with wheat, as shewn by the analysis of the two plants. Yet, as a matter of fact, it is found that heavy applications of superphosphate pay with turnips, greatly increasing the crop, and that phosphoric anhydride is rarely a necessary application for wheat. The explanation of this curious result is supplied by the facts that the turnip has little power of absorbing the combined phosphoric anhydride of the soil, but the wheat plant has that power in a marked degree.

Losses and Gains in Sugar-cane Soils.

It will be interesting at this point to endeavour to obtain a clear idea of what are the losses and gains in our soils. The losses and gains in humus have already been considered, we now need only pay attention to the losses and gains in nitrogen, phosphoric acid, and potash. The actual losses to the soil of these constituents will take place entirely from the available plant food, we will therefore now draw up an available plant food account.

Dr. **Available Plant Food Account.** *Cr.*

	Nitrogen.	Phosphoric Anhydride.	Potash.	Sulphuric Acid, &c.		Nitrogen.	Phosphoric Anhydride.	Potash.	Sulphuric Acid, &c.
1. To balance of available plant food carried over from last a/c.	—	—	—	—	1. By canes ...	34	25	45	—
2. To potential plant food rendered available by tillage.	—	—	—	—	2. By tops, trash, and roots.	—	—	—	—
3. To subsoil per earth-worm casts.	—	—	—	—	3. By snatch crops and other rotation crops.	—	—	—	—
4. To farm-yard manure.	—	—	—	—	4. By drainage water (for nitrates, sulphates and chlorides).	—	—	—	—
5. To leguminous green-dressing.	—	—	—	—					
To minerals by deep roots of leguminosæ from subsoil.	—	—	—	—					
6. To artificial manure.	—	—	—	—					
	—	—	—	—		—	—	—	—

The Fate of Waste Products.

The course universally pursued in Barbados in regard to the cane crop is to feed the tops to the plantation stock, to use the trash partly for littering the pens and for spreading on the fields of young canes, while the roots are either allowed to remain in the fields or are used, on account of the adhering soil, to mould the pens. Lawes and Gilbert have found that with animals kept in covered stalls in which every precaution is taken to preserve and retain all the excreta both solid and liquid, 75 to 95 per cent. of the nitrogen in the food and 95 to 97 per cent. of the mineral

constituents in the food may be recovered. This cannot be effected in the case of our estate animals which work not only in the fields but on the roads: but taking into account the fact that purchased foodstuffs, such as crushed oil-cake, are used to a considerable extent to supplement the food on the estate, that filter press cake is fed to the cattle as well as in some instances molasses, I think we may fairly conclude that the equivalent of the nitrogen, phosphoric anhydride and potash in the tops, trash and roots are returned to the soil in the farmyard manure.

The canes are crushed and the megass used as fuel. This megass contains a small proportion of the nitrogen and potash and about a third of the phosphoric anhydride in the canes. In burning the megass all the nitrogen and some of the phosphoric anhydride and potash are lost, but the value of the megass as fuel far outweighs this consideration. The filter press cake contains nearly half the phosphoric anhydride and a small proportion of the nitrogen of the canes. This as we have seen is recovered. The molasses contains half the nitrogen and three fifths of the potash in the canes. The amounts of nitrogen, phosphoric anhydride and potash in the sugar are very small indeed.* Molasses therefore is the most serious source of loss in nitrogen and mineral plant food, but the high price of muscovado molasses relatively to the rum that could be manufactured from it much more than makes up for this loss in manurial substances.

On the whole we may conclude that in respect to valuable plant food, the farmyard manure on the debit side (gain) balances the tops, trash, and roots on the credit side (loss): we are therefore left with the following sources of loss—the canes, other crops sold off the land and nitrogen lost as nitrates in drainage. We have already estimated that 20 tons of Bourbon canes (stalks) remove nitrogen 34 pounds, phosphoric anhydride 26 pounds (equal to 55 pounds phosphate of lime) potash 46 pounds. Lawes and Gilbert found that 36–46 pounds of nitrogen per acre were lost in the drainage water from arable land; and anyone who has followed the analysis of the Barbados water supply during different periods of the year will not fail to see that a notable proportion of the nitrogen applied to our soils is yearly lost in the drainage water.

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* The writer had the advantage of perusing a paper by Mr. Noël Deerr on "The distribution of the constituents of the sugar-cane in a Demerara factory and their utilisation as manure" to appear in Vol. II. No. 3. of the West Indian Bulletin.

Undoubtedly the most important source of gain to the soil is the plant food rendered available by tillage, and too much stress cannot be laid upon this item which appears on the debit side. The gain in nitrogen by leguminous crops either fed to the animals to increase the farmyard manure, or turned directly under in the field is also an important consideration.

The last source of gain and the last resource of the planter is artificial manure.

In addition to the humus account and available plant food account I drew your attention to three other forms of accounts namely the potential plant food account, the non-available account, and the subsoil general account. These forms will serve to epitomize a good deal of the result of our studies of the formation of soils : they exhibit the most important, if not all the sources of loss and gain to the soil and subsoil and would as it were constitute, if only we could supply figures, a system of soil book-keeping by double entry.

POTENTIAL PLANT FOOD ACCOUNT.

Dr. *Cr.*

	Nitrogen.	Phosphoric Anhydride.	Potash.	Sulphuric Acid, &c.		Nitrogen.	Phosphoric Anhydride.	Potash.	Sulphuric Acid, &c.
1. To balance of potential plant food carried over from last a/c.	—	—	—	—	By available plant food a/c (per tillage).	—	—	—	—
2. To rocks disintegrated.	—	—	—	—					
3. To subsoil per earthworm casts.	—	—	—	—					
4. To humus of farmyard manure.	—	—	—	—					
5. To humus of leguminous crop.	—	—	—	—					
	—	—	—	—		—	—	—	—

Soil Constituents Account (Non-Available).

Dr. *Cr.*

	Nitrogen.	Phosphoric Anhydride.	Potash.	Sulphuric Acid, &c.		Nitrogen.	Phosphoric Anhydride.	Potash.	Sulphuric Acid, &c.
To rocks partially disintegrated.	—	—	—	—	By potential plant food a/c for materials supplied.	—	—	—	—
	—	—	—	—		—	—	—	—

Subsoil Account (Potential and Available).

Dr. *Cr.*

	Nitrogen.	Phosphoric Anhydride.	Potash.	Sulphuric Acid, &c.		Nitrogen.	Phosphoric Anhydride.	Potash.	Sulphuric Acid, &c.
1. To balance of plant food carried over.	—	—	—	—	1. By earthworms for humus and mineral particles.	—	—	—	—
2. To rocks disintegrated by aeration, tillage, and plant roots.	—	—	—	—	2. By deep roots of leguminosæ and crop plants.	—	—	—	—
	—	—	—	—		—	—	—	—

Before leaving this aspect of the subject I wish to draw your attention to the fact that it is not the object of the practical planter to maintain the amount of each constituent of potential plant food exactly at the figure at which it stands to-day. I have already alluded to the fact that the supply of iron, magnesia, and often of

Stubbs of Louisiana, of Professor Maxwell of Hawaii, and from the Dodds Reports.

The purple cane removed from the soil in

—	Pounds of			
	Nitrogen.	Phosphoric anhydride.	Potash.	Total mineral matter.
Louisiana, per ton of cane ...	1·08	1·04	1·22	11·2
„ per 20 tons of cane	21·6	20·8	24·4	224·
Hawaii, per ton of cane ...	2·82	1·3	6·8	18·1
„ per 20 tons of cane ...	56·4	26·	136·	362·

The average of the determinations of several years shew that the Bourbon cane removed from the soil in

—	Pounds of		
	Nitrogen.	Phosphoric anhydride.	Potash.
Barbados, per ton of cane	1·68	1·3	2·28
„ per 20 tons of cane ...	33·6	26·	45·6

These results show considerable differences one from the other, and they are doubtless in great measure due to differences in the composition of the different soils. If we judged from the analyses of the cane grown in the rich Hawaiian soil, we should conclude that large applications of nitrogen and potash manures were necessary; if we judged from the cane grown in the soils of Louisiana, we should conclude that much smaller applications were necessary; and if we looked at the Barbados results (which, being

obtained with another variety of cane, are not strictly comparable with the Louisiana and Hawaiian canes) we should see that they point to a conclusion different from either of the two former.

In other words, plants, like animals, consume food extravagantly or economically according to the supply. A plant grown in a virgin soil, as extraordinarily rich in plant food as some of those in Hawaii, will be extravagant in the amount it takes up compared with similar plants grown in a poorer soil ; but it does not at all follow that the large amount of food taken up by the plant is necessary to produce the maximum crop, and indeed, a careful study of the question will soon lead to the conclusion that the analysis of the plant—which even takes up compounds of soda, titanium, manganese, substances that we believe are not necessary at all—will not tell us how to manure our cane fields.

A conspicuous example may be quoted from English agriculture in support of this conclusion ; it is the well-known comparison of the turnip and wheat in relation to the supply of phosphoric anhydride. Turnips take up little phosphoric anhydride compared with wheat, as shewn by the analysis of the two plants. Yet, as a matter of fact, it is found that heavy applications of superphosphate pay with turnips, greatly increasing the crop, and that phosphoric anhydride is rarely a necessary application for wheat. The explanation of this curious result is supplied by the facts that the turnip has little power of absorbing the combined phosphoric anhydride of the soil, but the wheat plant has that power in a marked degree.

Losses and Gains in Sugar-cane Soils.

It will be interesting at this point to endeavour to obtain a clear idea of what are the losses and gains in our soils. The losses and gains in humus have already been considered, we now need only pay attention to the losses and gains in nitrogen, phosphoric acid, and potash. The actual losses to the soil of these constituents will take place entirely from the available plant food, we will therefore now draw up an available plant food account.

Available Plant Food Account.

Dr. *Cr.*

	Nitrogen.	Phosphoric Anhydride.	Potash.	Sulphuric Acid, &c.		Nitrogen.	Phosphoric Anhydride.	Potash.	Sulphuric Acid, &c.
1. To balance of available plant food carried over from last a/c.	—	—	—	—	1. By canes ...	34	25	45	—
2. To potential plant food rendered available by tillage.	—	—	—	—	2. By tops, trash, and roots.	—	—	—	—
3. To subsoil per earth-worm casts.	—	—	—	—	3. By snatch crops and other rotation crops.	—	—	—	—
4. To farm-yard manure.	—	—	—	—	4. By drainage water (for nitrates, sulphates and chlorides).	—	—	—	—
5. To leguminous green-dressing.	—	—	—	—					
To minerals by deep roots of leguminosæ from subsoil.	—	—	—	—					
6. To artificial manure.	—	—	—	—					
	—	—	—	—		—	—	—	—

The Fate of Waste Products.

The course universally pursued in Barbados in regard to the cane crop is to feed the tops to the plantation stock, to use the trash partly for littering the pens and for spreading on the fields of young canes, while the roots are either allowed to remain in the fields or are used, on account of the adhering soil, to mould the pens. Lawes and Gilbert have found that with animals kept in covered stalls in which every precaution is taken to preserve and retain all the excreta both solid and liquid, 75 to 95 per cent. of the nitrogen in the food and 95 to 97 per cent. of the mineral

constituents in the food may be recovered. This cannot be effected in the case of our estate animals which work not only in the fields but on the roads: but taking into account the fact that purchased foodstuffs, such as crushed oil-cake, are used to a considerable extent to supplement the food on the estate, that filter press cake is fed to the cattle as well as in some instances molasses, I think we may fairly conclude that the equivalent of the nitrogen, phosphoric anhydride and potash in the tops, trash and roots are returned to the soil in the farmyard manure.

The canes are crushed and the megass used as fuel. This megass contains a small proportion of the nitrogen and potash and about a third of the phosphoric anhydride in the canes. In burning the megass all the nitrogen and some of the phosphoric anhydride and potash are lost, but the value of the megass as fuel far outweighs this consideration. The filter press cake contains nearly half the phosphoric anhydride and a small proportion of the nitrogen of the canes. This as we have seen is recovered. The molasses contains half the nitrogen and three fifths of the potash in the canes. The amounts of nitrogen, phosphoric anhydride and potash in the sugar are very small indeed.* Molasses therefore is the most serious source of loss in nitrogen and mineral plant food, but the high price of muscovado molasses relatively to the rum that could be manufactured from it much more than makes up for this loss in manurial substances.

On the whole we may conclude that in respect to valuable plant food, the farmyard manure on the debit side (gain) balances the tops, trash, and roots on the credit side (loss): we are therefore left with the following sources of loss—the canes, other crops sold off the land and nitrogen lost as nitrates in drainage. We have already estimated that 20 tons of Bourbon canes (stalks) remove nitrogen 34 pounds, phosphoric anhydride 26 pounds (equal to 55 pounds phosphate of lime) potash 46 pounds. Lawes and Gilbert found that 36–46 pounds of nitrogen per acre were lost in the drainage water from arable land; and anyone who has followed the analysis of the Barbados water supply during different periods of the year will not fail to see that a notable proportion of the nitrogen applied to our soils is yearly lost in the drainage water.

* The writer had the advantage of perusing a paper by Mr. Noël Deerr on "The distribution of the constituents of the sugar-cane in a Demerara factory and their utilisation as manure" to appear in Vol. II. No. 3, of the West Indian Bulletin.

and is one of the many instances of the value, as a guide to practice, of exact scientific knowledge.

Precipitated phosphate is dicalcic phosphate, and basic slag contains what is chemically known as a tetracalcic phosphate ; both of these forms are soluble in the acid exudations of plant roots ; precipitated phosphate is fairly soluble in carbonic anhydride water (which, as we know, exists in soils) ; basic slag phosphate is slightly soluble in carbonic anhydride water ; both forms are readily soluble in 1 per cent. citric acid. Therefore we may regard both as readily available forms—but as they are not soluble in rain water they are not diffusible, the plant roots have to come to the phosphate instead of (as in the case of superphosphate) the phosphate going to the plant roots. At one time our planters were divided into two camps, one of which thought that soluble, and as they called them acid, phosphates, were actually harmful to the canes—in fact they believed this form of phosphoric acid to be actually responsible for the fungus. I do not think that any good evidence has been adduced to support this idea, and I do not think there is any conclusive evidence to show that basic slag is as efficient as superphosphate (soluble phosphate) in soils containing the quantity of carbonate of lime common to Barbados soils. Nor do I know of any evidence to support the statement that the unused phosphate from basic slag remains longer available in the soil than the unused phosphate from superphosphate.

In my opinion, when you are dealing with soils containing a half per cent. and upwards of carbonate of lime (and this is the case with the majority of Barbados soils), if phosphoric anhydride is wanted at all, phosphate soluble in water (such as superphosphate, dissolved guano, &c.) are the forms to use ; and you will apply 25 pounds phosphoric anhydride equal to about 50 pounds phosphate of lime, an amount furnished by about 140 pounds of good commercial superphosphate. If your soil is deficient in carbonate of lime, then you must use an available but not acid form of phosphate such as is found in basic slag phosphate, precipitated phosphate, and high grade raw Peruvian guano (the latter, however, contains nitrogen) ; in this case you must double the amount and the cost of the phosphoric acid application.

I may mention in passing that, when the amount of phosphoric anhydride is stated, by multiplying it by 2·18 you find the corresponding amount of (tricalcic) phosphate of lime ; this is

useful to remember as both terms frequently occur in records of analyses of manures.

Now, gentlemen, you will probably be ready with this question, "We usually apply our manures in a ready mixed condition. What must be the composition of this manure to carry out your recommendations?" The following supplies the answer:—

Multiply the percentage of any constituent by 22·4 and the result will be the number of pounds of that constituent in a ton of manure.

An early cane manure, consisting of a mixture of dissolved Peruvian guano and sulphate of potash, or consisting of a mixture of sulphate of ammonia, superphosphate, and sulphate of potash, containing by analysis

4 per cent. nitrogen,
18 per cent. soluble phosphate of lime,
18 per cent. potash,

and applied at the rate of one ton to nine acres, will approximately supply 10 pounds nitrogen, 45 pounds soluble phosphate of lime, and 45 pounds of potash. This practically realises the applications above recommended for the young plant-canes, and would be followed in June to August by the applications of sulphate of ammonia or nitrate of soda.

This manure should be applied in a circle about one foot from the centre of the cane hole, and should be worked into the first two or three inches of the surface soil.

Before leaving this subject, I may remark that it seems that the cane plant while young is unable readily to assimilate the combined phosphoric acid and potash of the soil, and apparently it is at this stage that it can derive most benefit from the application of these substances in a very readily available form. When the cane arrives at a period of vigorous growth with adequate root system, in Barbados soils it can apparently obtain sufficient phosphoric acid and potash from the available materials in the soil.

Manuring of Ratoons.

There are at present no experimental results available in Barbados in regard to the manuring of ratoons. The same principles, however, apply both to ratoons and to plant-canes. Where several

crops of ratoons are grown, it is obvious that a proportionate increase should be made in the application of farmyard manure and trash, in order to replace the humus destroyed and plant food removed in the canes and waste materials (tops, trash) of the crops. It is also the general opinion of planters that a larger total application of nitrogen in an active form may be employed with advantage than in the case of plant-canes.

A provisional recommendation for ratoons is to apply 1 cwt. per acre of nitrate of soda (which contains about 17 pounds nitrogen) as soon as the stools spring, to follow this up in June by an application of 3 cwt. of a manure containing 12 per cent. nitrogen, 12 per cent. soluble phosphate and 6 per cent. potash, and if the rainfall is favourable, to further apply 1 cwt. of sulphate of ammonia in July or August.

Valuation of Manures.

In forming an estimate of the value of artificial manures, the ideal method would be to show their value in respect to their power of increasing the crop. This, however, is not practicable, and the valuation of the Agricultural Society aims at showing the relative commercial value of the different manures offered for sale in this market.

You will notice by reference to the analysis book of the Society that, per ton of mixed or compounded manures, 1 per cent. of nitrogen in the form of sulphate of ammonia or nitrate of soda is valued at $3.64. Now 1 per cent. is one part per 100, and as a ton contains 2,240 pounds, it is evident that 1 per cent. is equivalent to 22·4 pounds per ton, and that 22·4 pounds of nitrogen is valued at $3.64.

Similarly per ton of mixed manure—

1 per cent. of soluble phosphate is valued at $0.90
1 „ „ available „ „ $0.70
1 „ „ insoluble „ „ $0.25
1 „ „ potash (as sulphate or nitrate) is valued at $1.30

In every case 1 per cent. is equivalent to 22·4 pounds per ton.

Every purchaser of manure in this island is *entitled* to receive from the merchant an invoice or bill of parcel showing the percentage of nitrogen, soluble phosphate, insoluble phosphate and

potash contained by the manure. The merchant is bound to supply this, and it is not within his option to refrain from doing so because the buyer does not demand it.

Moreover, the Analytical Committee of the Society take samples of practically every cargo of manure brought to this island and forward them for analysis to the Government Chemist.

Planters, therefore, have ready means of assuring themselves that they are getting the manure they want and that the price charged for it is a fair one.

Rotation of Crops.

I now ask your attention to that well-known system of crop-growing, so widely practised in general farming, called the rotation of crops ; and I propose to illustrate the system by describing briefly an English course of rotation called the Norfolk rotation. I do so, not because it is a rotation that we could practise in this island, but because it affords an instructive example of the principles underlying a good rotation.

The Norfolk rotation is illustrated by the diagram herewith, and is made up of the following : (1) roots, (2) barley (grain), (3) clover (leguminous fodder), (4) wheat (grain).

Roots (such as turnips or mangels) are sown in late spring or during summer ; this permits of thorough tillage between the autumn of the preceding year when the wheat is reaped and the sowing of the roots. During their growth they admit of thorough weeding. A root crop is therefore a cleaning crop. It is fed to the animals on the farm, often on the very field—therefore it is not an exhausting crop; for the manurial residues are returned to the soil.

Of *Barley*, the grain is sold off the farm and is a source of pecuniary income. The straw is consumed on the farm ; this is an exhausting crop.

Clover is a leguminous fodder crop, fed on the farm. Its manurial residues enrich the land in stored up atmospheric nitrogen. It is a renovating crop.

Of *Wheat*, the grain is sold off the farm and is a source of pecuniary income. The straw is consumed on the farm. It is an exhausting and fouling crop.

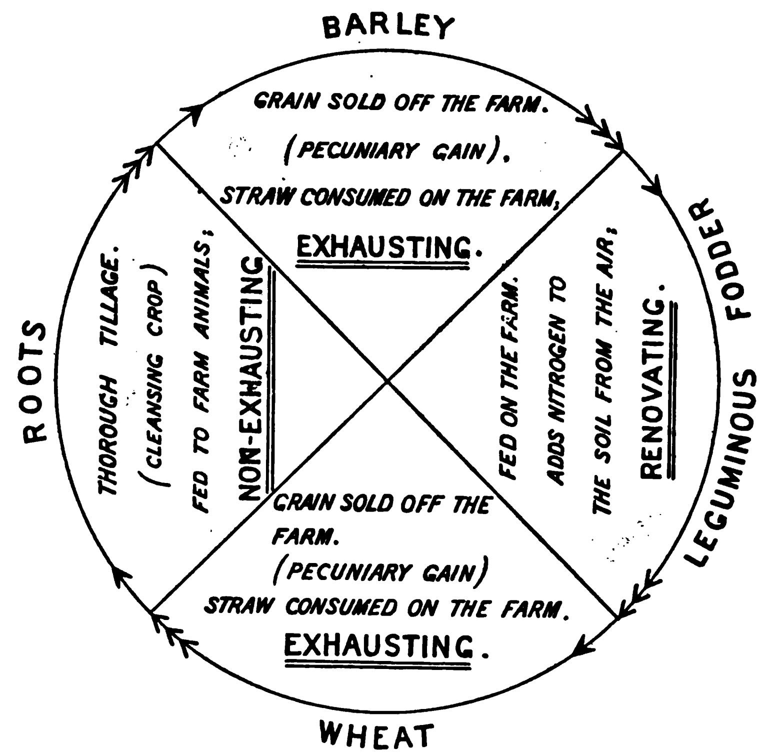

Diagram illustrating the rotation of crops in English agriculture.

Now if I had time to go into details of this rotation, such as the manures used, land preparation, time of sowing and reaping, you would have no difficulty in gathering the following substantial advantages as accruing to the farmer.

The crops are sowed and reaped at different times, so labourers, animals, and implements are more or less continually employed ; an obviously economical arrangement, as a given number of labourers, horses, and implements can work a maximum area of land.

There is a continuous supply of food for farm animals (that means a minimum purchase of oil cake), and the farm is highly self-supporting.

The leguminous crop enriches the soil in nitrogen. The manurial residues of the crops fed on the farm are returned to the land in the farmyard manure.

The roots of different crops penetrate to different depths ; different crops consume different soil constituents in different proportions ; both of these lead to an economical utilisation of the resources of the soil.

The inclusion of a root (fallow crop) in the course permits, as indicated above, the thorough tilling and clearing of the land at least once in the course.

Insect and fungoid pests are kept down. Each pest usually lives on a particular crop. If this crop be always on the same field the pest has always a food supply at hand and this leads to an increase of the disease. If by growing another crop on the field the food supply is cut off, the pest disappears, or at all events its increase is checked.

For all the above reasons the crops of a rotation system are always more vigorous, and the question arises for your consideration, as practical men, whether, with the present low prices of sugar, some rotation could not be devised by you to secure some of the advantages outlined above.

In Louisiana the rotation is :—

Maize,
Louisiana cow pea (leguminous fodder),
Plant-canes,
Ratoon canes.

In Java one rotation is :—

Plant-canes,
Ratoon canes,
Rice,
Rice second growth,
Rice
Plant-canes

In Barbados there is also a trace of rotation in say a course of :—

Plant-canes,
First ratoon,
Second ratoons,
Beans, sweet potatoes, Guinea corn, imphee, and the like.

Can we not make our estates more self-supporting, can we not grow more leguminous fodder crops, can we not save a certain amount of money now spent on artificial manures, can we not utilise the local market and those of neighbouring islands by the growth of provisions to a greater extent, with pecuniary advantage to ourselves and with advantage to the vigour of our crops?

LECTURE V.

HINTS ON THE PLANTING AND CULTIVATION OF THE SUGAR-CANE AND INTERMEDIATE CROPS.

By JOHN R. BOVELL, F.L.S., F.C.S.,

Agricultural Superintendent of Sugar-cane Experiments, Barbados.

Although the title of my lecture is "Hints on the planting and cultivation of the sugar-cane and intermediate crops," it ought rather to be: "A few agricultural problems in connection with the planting and cultivation of the sugar-cane and intermediate crops, with some suggestions for their solution."

Some of these problems have, I am aware, engaged the attention of many here to-day, and I shall be much obliged to anyone for information which may help to solve some of the knotty points. I may here say that, on my part, I shall be very pleased if at any time I can assist those who will assist in arranging experiments for elucidating any of the agricultural problems I now propose to bring before you.

Cost of Cane Production.

As you are aware, I have, before this,* pointed out that the cost of growing sugar-canes in Barbados is from 13*s*. to 14*s*. per ton,

* *West Indian Bulletin*, Vol. I., p. 64.

crops of ratoons are grown, it is obvious that a proportionate increase should be made in the application of farmyard manure and trash, in order to replace the humus destroyed and plant food removed in the canes and waste materials (tops, trash) of the crops. It is also the general opinion of planters that a larger total application of nitrogen in an active form may be employed with advantage than in the case of plant-canes.

A provisional recommendation for ratoons is to apply 1 cwt. per acre of nitrate of soda (which contains about 17 pounds nitrogen) as soon as the stools spring, to follow this up in June by an application of 3 cwt. of a manure containing 12 per cent. nitrogen, 12 per cent. soluble phosphate and 6 per cent. potash, and if the rainfall is favourable, to further apply 1 cwt. of sulphate of ammonia in July or August.

VALUATION OF MANURES.

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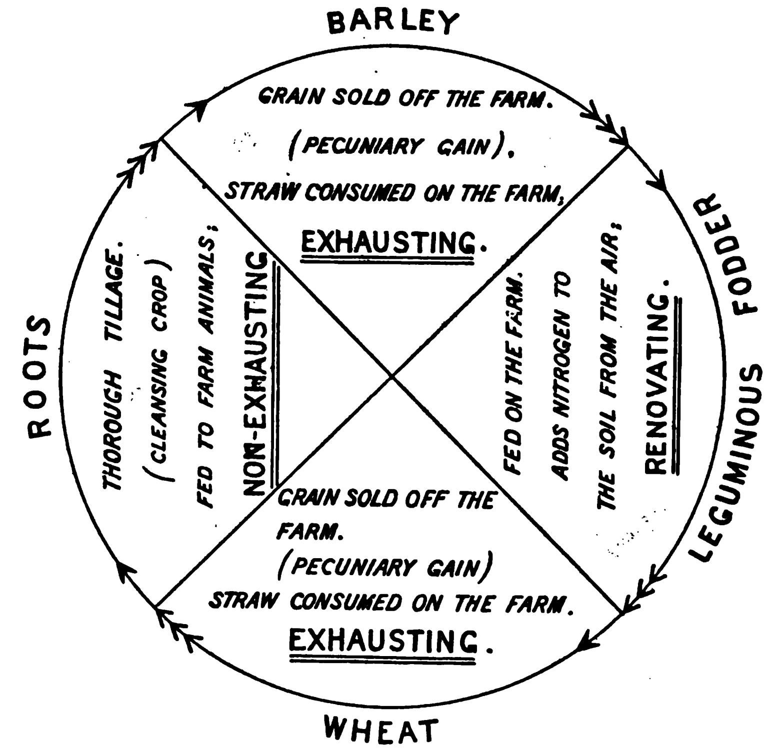

Diagram illustrating the rotation of crops in English agriculture.

Now if I had time to go into details of this rotation, such as the manures used, land preparation, time of sowing and reaping, you would have no difficulty in gathering the following substantial advantages as accruing to the farmer.

The crops are sowed and reaped at different times, so labourers, animals, and implements are more or less continually employed ; an obviously economical arrangement, as a given number of labourers, horses, and implements can work a maximum area of land.

There is a continuous supply of food for farm animals (that means a minimum purchase of oil cake), and the farm is highly self-supporting.

The leguminous crop enriches the soil in nitrogen. The manurial residues of the crops fed on the farm are returned to the land in the farmyard manure.

The roots of different crops penetrate to different depths ; different crops consume different soil constituents in different proportions ; both of these lead to an economical utilisation of the resources of the soil.

The inclusion of a root (fallow crop) in the course permits, as indicated above, the thorough tilling and clearing of the land at least once in the course.

Insect and fungoid pests are kept down. Each pest usually lives on a particular crop. If this crop be always on the same field the pest has always a food supply at hand and this leads to an increase of the disease. If by growing another crop on the field the food supply is cut off, the pest disappears, or at all events its increase is checked.

For all the above reasons the crops of a rotation system are always more vigorous, and the question arises for your consideration, as practical men, whether, with the present low prices of sugar, some rotation could not be devised by you to secure some of the advantages outlined above.

In Louisiana the rotation is :—

Maize,
Louisiana cow pea (leguminous fodder),
Plant-canes,
Ratoon canes.

In Java one rotation is :—

Plant-canes,
Ratoon canes,
Rice,
Rice second growth,
Rice
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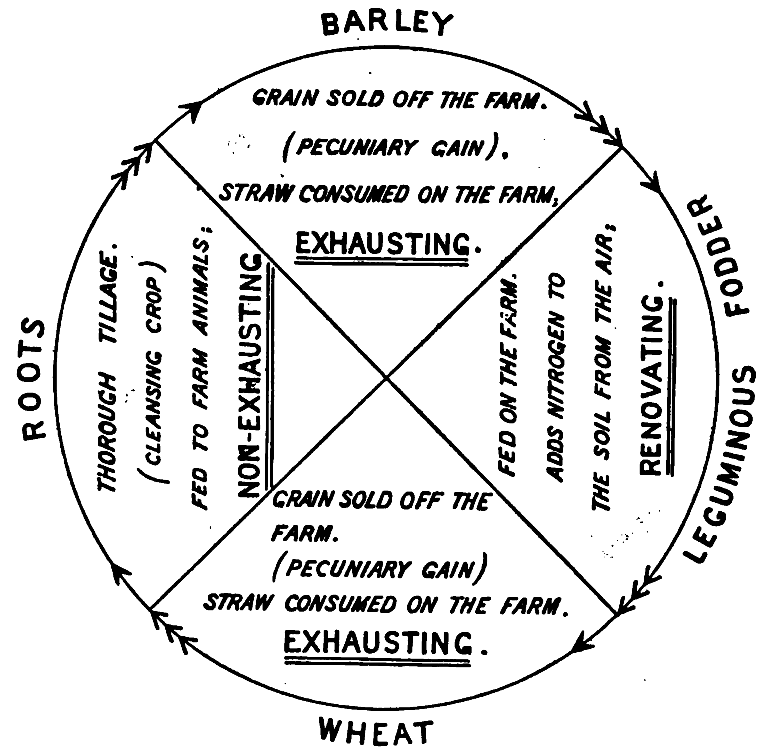

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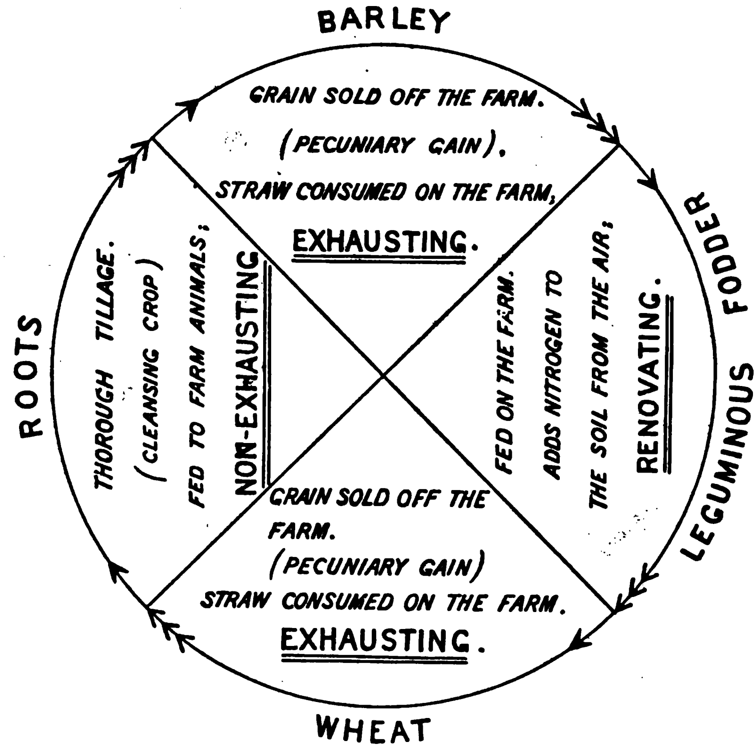

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HINTS ON THE PLANTING AND CULTIVATION OF THE SUGAR-CANE AND INTERMEDIATE CROPS.

By JOHN R. BOVELL, F.L.S., F.C.S.,

Agricultural Superintendent of Sugar-cane Experiments, Barbados.

Although the title of my lecture is "Hints on the planting and cultivation of the sugar-cane and intermediate crops," it ought rather to be: "A few agricultural problems in connection with the planting and cultivation of the sugar-cane and intermediate crops, with some suggestions for their solution."

Some of these problems have, I am aware, engaged the attention of many here to-day, and I shall be much obliged to anyone for information which may help to solve some of the knotty points. I may here say that, on my part, I shall be very pleased if at any time I can assist those who will assist in arranging experiments for elucidating any of the agricultural problems I now propose to bring before you.

Cost of Cane Production.

As you are aware, I have, before this,* pointed out that the cost of growing sugar-canes in Barbados is from 13*s.* to 14*s.* per ton,

* *West Indian Bulletin*, Vol. I., p. 64.

and that this is higher than in most other sugar-producing countries. While on the subject of the cost of growing sugar-canes it may not be without interest if I put before you the latest data I have on the subject. Quite recently I have obtained copies of the accounts of two estates in this island for the past eleven years. These estates were cultivated without the assistance of the Agricultural-in-Aids Act, so the assumption is that everything was bought in the cheapest and best market. Assuming that, under present conditions, thirteen and a half tons of canes make one ton of sugar, that a hogshead is seven-eighths of a ton, and that nine bags are equal to a hogshead, the average cost of growing and manufacturing sugar on the two estates was 17*s.* 10*d.* per ton of canes. As the cost of manufacture, upkeep of buildings, cost of hogsheads, &c., is 5*s.* 5*d.* per ton, the average net cost of a ton of canes on the two estates was 12*s.* 5*d.* As the returns of these two estates were given in hogsheads and bags, I may mention that a buyer of sugar in this island has recently ascertained, from the weight of the hogsheads and bags of sugar bought this year, that the average net weight of a hogshead of muscovado sugar is 2,000 lb., and, including bags of dark crystals, it requires on the average nine bags to net 2,000 lb.

In Jamaica, according to Mr H. H. Cousins, M.A., F.C.S., the Government Agricultural and Analytical Chemist at Mesopotamia, in the parish of Westmoreland, where the canes are all weighed and careful accounts kept, the cost is 5*s.* 6*d.* per ton delivered at the works.

In Trinidad factory proprietors buy canes from cane-farmers at from 9*s.* to 10*s.* per ton delivered at the factories. The quantity so bought in 1900 was something like 106,000 tons—sufficient to make about 10,000 tons of sugar.

In Antigua it costs 11*s.* to grow a ton of canes. In Queensland 10*s.* per ton is paid for canes delivered at the factories. It is therefore evident that in Barbados the cost of growing canes is higher than in any of the countries mentioned.

In the United States of America the beet root industry is growing very fast. In the official report presented to Congress from the Agricultural Department the official reporter states that he knows of no other single product which can be grown on a farm to any considerable extent that will compare with the profits derived from

beet. He states that on starting a factory it has been difficult to get the farmers to contract to raise beets, but after the experience of one or two years it ceases to be a question as to who can be induced to sign the contracts, and becomes a question among the farmers as to who can secure them.

In Cuba and Porto Rico the output of cane-sugar is rapidly increasing. The former island, which a few years ago made 200,000 tons of sugar, made 600,000 this year, is estimated to make 800,000 tons next year, and it is expected that before long the annual crop will reach 2,000,000 tons. It is therefore extremely probable that in a few years we shall lose our present market in the United States and have to look somewhere else.

If we go to the English market, we shall have to compete with the continental beet-sugar ; and not only with what is sent there now, but, as foreign beet-sugar will also be shut out of the United States market most of it will probably go to the English market as well.

I am told on reliable authority that beet-sugar can be placed, without bounties, on the English markets at 1*d.* per lb., or £9 6*s.* 8*d.* per ton. As the cost of marketing a ton of sugar is about £2, the cost of manufacturing in a factory about the same, the interest on the capital invested in the factory, depreciation, &c., another £1 8*s.*, there would be left £3 18*s.* 6*d.* to the planter for his canes. As in a central factory nine and a half tons of canes will make a ton of sugar, a ton of canes would be worth about 8*s.* 3*d.*, when dark crystals are selling in England at £9 6*s.* 8*d.* per ton. So to be on equal terms with the beet growers, the Barbados planters' canes should not cost more than 8*s.* 3*d.* per ton to produce.

From what I have said you will see that, unless we reduce the cost of producing a ton of canes, it will be impossible for the estates to go on under the conditions that will then exist ; and, as there is nothing else that I know of to take the place of the cane, our condition will be deplorable. Even now with the present prices, it is very doubtful whether sugar can pay the cost of production on seventy-five per cent. of the ordinary muscovado estates in the island.

On Friday the 6th instant (September, 1901), I asked a gentleman who is a large buyer of sugar to tell me what was the value of sugar and molasses that day. He said sugar was worth $1.35 per

crops of ratoons are grown, it is obvious that a proportionate increase should be made in the application of farmyard manure and trash, in order to replace the humus destroyed and plant food removed in the canes and waste materials (tops, trash) of the crops. It is also the general opinion of planters that a larger total application of nitrogen in an active form may be employed with advantage than in the case of plant-canes.

A provisional recommendation for ratoons is to apply 1 cwt. per acre of nitrate of soda (which contains about 17 pounds nitrogen) as soon as the stools spring, to follow this up in June by an application of 3 cwt. of a manure containing 12 per cent. nitrogen, 12 per cent. soluble phosphate and 6 per cent. potash, and if the rainfall is favourable, to further apply 1 cwt. of sulphate of ammonia in July or August.

Valuation of Manures.

In forming an estimate of the value of artificial manures, the ideal method would be to show their value in respect to their power of increasing the crop. This, however, is not practicable, and the valuation of the Agricultural Society aims at showing the relative commercial value of the different manures offered for sale in this market.

You will notice by reference to the analysis book of the Society that, per ton of mixed or compounded manures, 1 per cent. of nitrogen in the form of sulphate of ammonia or nitrate of soda is valued at \$3.64. Now 1 per cent. is one part per 100, and as a ton contains 2,240 pounds, it is evident that 1 per cent. is equivalent to 22·4 pounds per ton, and that 22·4 pounds of nitrogen is valued at \$3.64.

Similarly per ton of mixed manure—

1 per cent. of soluble phosphate is valued at \$0.90
1 „ „ available „ „ \$0.70
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In every case 1 per cent. is equivalent to 22·4 pounds per ton.

Every purchaser of manure in this island is *entitled* to receive from the merchant an invoice or bill of parcel showing the percentage of nitrogen, soluble phosphate, insoluble phosphate and

potash contained by the manure. The merchant is bound to supply this, and it is not within his option to refrain from doing so because the buyer does not demand it.

Moreover, the Analytical Committee of the Society take samples of practically every cargo of manure brought to this island and forward them for analysis to the Government Chemist.

Planters, therefore, have ready means of assuring themselves that they are getting the manure they want and that the price charged for it is a fair one.

Rotation of Crops.

I now ask your attention to that well-known system of crop-growing, so widely practised in general farming, called the rotation of crops ; and I propose to illustrate the system by describing briefly an English course of rotation called the Norfolk rotation. I do so, not because it is a rotation that we could practise in this island, but because it affords an instructive example of the principles underlying a good rotation.

The Norfolk rotation is illustrated by the diagram herewith, and is made up of the following : (1) roots, (2) barley (grain), (3) clover (leguminous fodder), (4) wheat (grain).

Roots (such as turnips or mangels) are sown in late spring or during summer ; this permits of thorough tillage between the autumn of the preceding year when the wheat is reaped and the sowing of the roots. During their growth they admit of thorough weeding. A root crop is therefore a cleaning crop. It is fed to the animals on the farm, often on the very field—therefore it is not an exhausting crop; for the manurial residues are returned to the soil.

Of *Barley*, the grain is sold off the farm and is a source of pecuniary income. The straw is consumed on the farm ; this is an exhausting crop.

Clover is a leguminous fodder crop, fed on the farm. Its manurial residues enrich the land in stored up atmospheric nitrogen. It is a renovating crop.

Of *Wheat*, the grain is sold off the farm and is a source of pecuniary income. The straw is consumed on the farm. It is an exhausting and fouling crop.

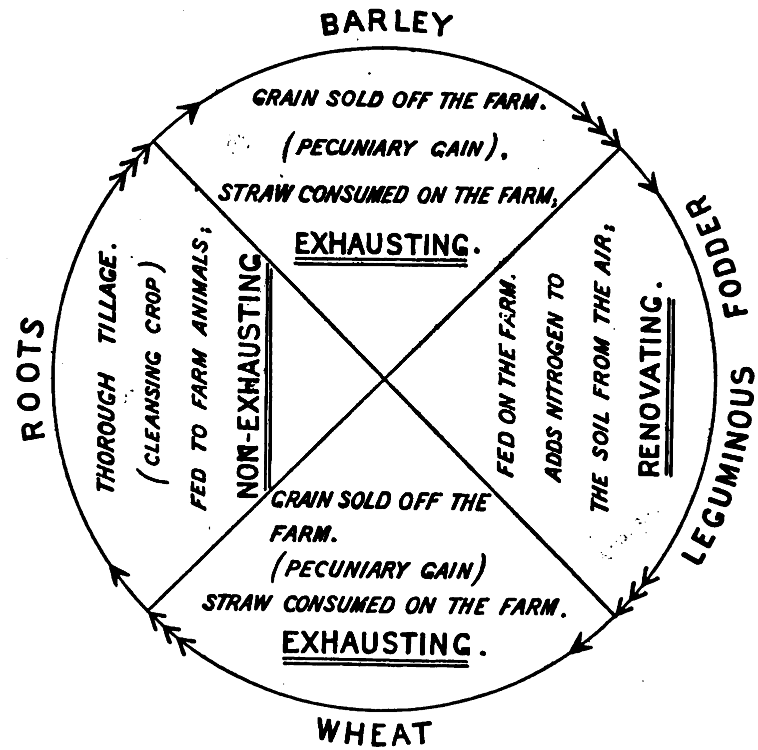

Diagram illustrating the rotation of crops in English agriculture.

Now if I had time to go into details of this rotation, such as the manures used, land preparation, time of sowing and reaping, you would have no difficulty in gathering the following substantial advantages as accruing to the farmer.

The crops are sowed and reaped at different times, so labourers, animals, and implements are more or less continually employed ; an obviously economical arrangement, as a given number of labourers, horses, and implements can work a maximum area of land.

There is a continuous supply of food for farm animals (that means a minimum purchase of oil cake), and the farm is highly self-supporting.

The leguminous crop enriches the soil in nitrogen. The manurial residues of the crops fed on the farm are returned to the land in the farmyard manure.

The roots of different crops penetrate to different depths ; different crops consume different soil constituents in different proportions ; both of these lead to an economical utilisation of the resources of the soil.

The inclusion of a root (fallow crop) in the course permits, as indicated above, the thorough tilling and clearing of the land at least once in the course.

Insect and fungoid pests are kept down. Each pest usually lives on a particular crop. If this crop be always on the same field the pest has always a food supply at hand and this leads to an increase of the disease. If by growing another crop on the field the food supply is cut off, the pest disappears, or at all events its increase is checked.

For all the above reasons the crops of a rotation system are always more vigorous, and the question arises for your consideration, as practical men, whether, with the present low prices of sugar, some rotation could not be devised by you to secure some of the advantages outlined above.

In Louisiana the rotation is :—

Maize,
Louisiana cow pea (leguminous fodder),
Plant-canes,
Ratoon canes.

In Java one rotation is :—

Plant-canes,
Ratoon canes,
Rice,
Rice second growth,
Rice
Plant-canes

In Barbados there is also a trace of rotation in say a course of :—

Plant-canes,
First ratoon,
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Beans, sweet potatoes, Guinea corn, imphee, and the like.

Can we not make our estates more self-supporting, can we not grow more leguminous fodder crops, can we not save a certain amount of money now spent on artificial manures, can we not utilise the local market and those of neighbouring islands by the growth of provisions to a greater extent, with pecuniary advantage to ourselves and with advantage to the vigour of our crops ?

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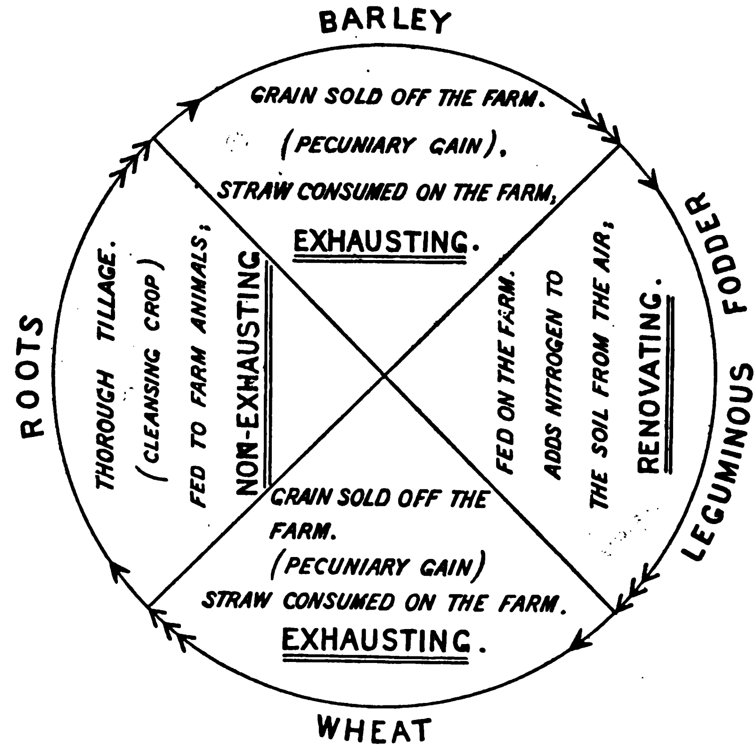

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As these bacteria grow older they take on all manner of distorted shapes. These distorted bacteria are called bacteroids.

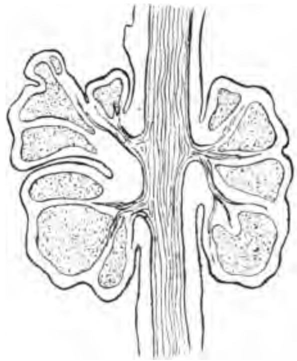

FIG. 29.—Root nodule of Bengal bean. Cut through lengthwise. (Adapted from Fischer.)

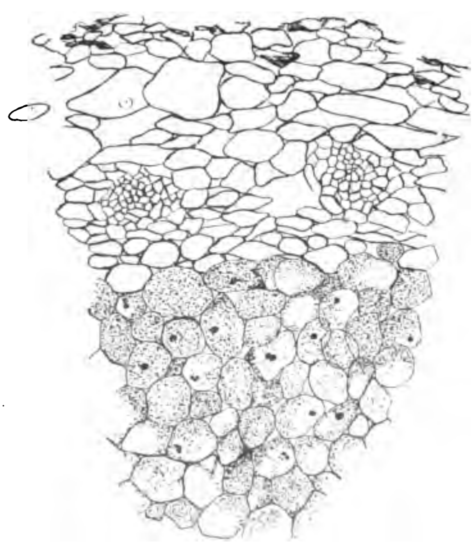

FIG. 30.—Root nodule of Bengal bean. Cut across. (From nature.) (Highly magnified.)

The formation of these bacteroids is a sign that the micro-organisms are dying and yielding up their protoplasmic contents to the plant, which begins to grow more vigorously. By the time the fruit of the plant arrives at maturity, the shrivelled empty nodules contain only remains of the bacteroids, together with a few healthy rods that remain in the soil, and serve as "seed material" for next year's nodules.

Although these bacteria are very similar in appearance and growth when viewed through the microscope, their action on plants,

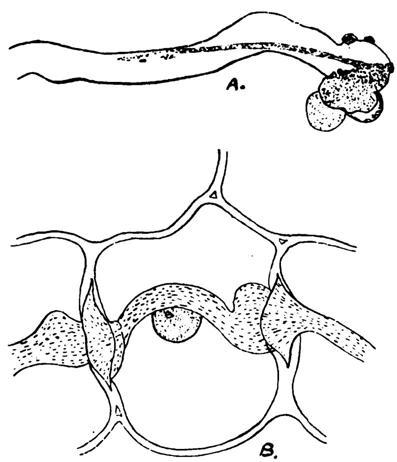

FIG. 31.—Invasion of leguminous roots by bacteria.
(a.) Entering a root hair.
(b.) Passing from cell to cell.
(After Fischer).

when investigated, is found to be different, the bacteria which produce numerous nodules on one genus of leguminous plants, being practically without effect on any other genus.

The bacteria find their way into the tissues of the plant by the root hairs. The hairs of a young leguminous plant, destitute as yet of nodules, pushing themselves everywhere into the water-filled crevices of the soil, come in contact with the bacteria or their spores (Fig. 31A).

The bacteria then enter the root hairs (Fig. 31B), passing on from cell to cell in the tissues of the root, where they multiply rapidly, all the time absorbing nitrogen from the atmosphere contained in the interstices of the soil. After a time the plant absorbs the substance of the bacterial cells. The precise way in which this is done is not clearly understood, but it is considered in all probability to be accomplished by means of a digestive ferment. The dissolved bacteria then appear to be taken up with and by the water containing the nutriment substances absorbed by the root hairs. This nutriment containing water passes from the root hairs into the fibro-vascular bundles of the roots, and thence onward through the fibro-vascular bundles of the stem until it reaches the leaves. This water, passing upward through the stem, is called the transpiration current. Having reached the leaves, some of this water is transpired through the stomata or air pores in the form of invisible vapour ; the remainder, under the influence of sunlight, combining with the carbon of the atmosphere to form carbohydrates of various kinds—that is, compounds of carbon and water. Cane-sugar is a carbohydrate, so is glucose or dextrose, levulose, maltose, starch, &c. According to Messrs. H. T. Brown, F.R.S., and G. H. Morris, Ph.D., F.I.C., the principal carbohydrate first formed in some plants is cane-sugar, which is, composed of twelve parts of carbon and eleven parts of water ($C_{12} H_{22} O_{11}$), or to bring it into line with the other sugars mentioned below, six parts of carbon united to five and one half parts of water. In addition to cane-sugar, they found in the leaves of *Tropæolum majus* glucose or dextrose—six parts of carbon and six parts of water ($C_6 H_{12} O_6$) —and other sugars like levulose and maltose.

As the liquid carbohydrates are formed, they pass out of the leaves through various tissues in the plant. Now, in bright sunshiny weather, when the leaves are assimilating very rapidly, carbohydrates are sometimes formed faster than the tissues can absorb them. When this occurs the surplus material is converted into starch—six parts carbon and five parts water ($C_6 H_{10} O_5$)—which remains in the cells of the leaves until assimilation ceases, which it regularly does at night. The starch grains are then dissolved, and in the form of soluble carbohydrates like glucose, maltose, &c., pass into the vascular bundles and are transferred in these conducting tissues through the leaf stalks into the stem. Thence they are conveyed to the young shoots and buds, or are carried down to the

roots, or, in short, transported to wherever they are required for the nutrition of the plant.

From what I have said, you will understand how desirable it is that the various problems in connection with green manuring should be investigated; and I do hope that some of you will help in the matter. If half-a-dozen planters in different parts of the island would take up, say, the question of which is the best plant to use for green manuring—sweet potato vines, woolly pyrol, Bengal beans, velvet beans, or some other leguminous plant—another half-a-dozen might carry out experiments to decide whether in green manuring it is desirable to allow the material to wither first or not; others might try and ascertain whether it would not be better to feed the green crops to the animals and apply the resultant manure to the soil rather than to bury the plants directly.

Suggested Experiments on Green Manuring.

Experiments of the sort suggested could for all practical purposes be easily carried out on estates. Take the experiment of sweet potato vines *versus* some leguminous plants. Let a planter choose a fairly level field of, as far as he can judge, uniform character; divide the field in half. Let him plant one half with sweet potato vines, the other half, say, with woolly pyrol. As soon as these plants arrive at the stage at which in ordinary estate practice they are turned under, let them be buried in one of the usual modes, such as under half a basket of farmyard manure placed at the side of the cane hole. Let all the other treatment of the field be exactly the same, and when the canes arrive at maturity let each half, or an equal portion of each half, of the field be crushed separately; the number of clarifiers, or parts of a clarifier (*i.e.*, the number of gallons of juice) ascertained, and the density by the ordinary Beaumé saccharometer noted. By experiments of this sort—which are easily and inexpensively carried out—planters will soon be able to decide for themselves which plant it is most profitable to use for green manuring, and so on with the several problems which I have suggested should be investigated.

Cultivation of Ratoons.

Forking ratoons is another operation as to the utility of which there is a wide difference of opinion—some planters strongly

advocating it, others as strongly objecting to the banks of the ratoon fields being tilled. I know of two instances where portions of a field of ratoons were forked. In one case the opposite quarters of the field were forked, and in the other strips of the field were thus tilled, the alternate strips being allowed to remain without being forked. In the first case—which was in a red soil district—the results were unfavourable to the forking; in the other—a black soil estate—the forked portions gave the best results.

Best Time for Forking Cane Land.

While on the subject of forking ratoons, might we not consider briefly the question of the best time for forking the land that is being prepared for canes, or in some cases after the canes are planted? In many instances fields that have been previously ploughed or forked are, in the months of January and February, reforked. Is it wise to break the soil to the depth we do at so late a time? Is the capillarity of the soil sufficiently restored in time for the roots, in the upper layers of the soil, to be supplied with moisture? Would it not be better to pulverize only two inches of the top soil to form a dust mulch, leaving the under layers sufficiently compacted to allow of the soil water rising to the upper strata?

We know that if the end of a piece of blotting paper, or a lamp wick, or the end of a towel be suspended so that the lower end just dips under the surface of a vessel of water, the water will gradually creep up until the top of the blotting paper, wick, or towel is reached. This water ascends by what is known as capillary attraction. If the strands at the top of the wick are widely separated, the power of raising the water is almost, if not entirely, destroyed. The same thing happens if the soil is too loose; consequently I think it possible that harm might be done by deeply tilling the surfaces of the fields at a late time.

Nessler once charged two tubes with air-dried loam, one loosely, the other tightly packed. He set them in water. At the end of three days the water had risen 11·00 inches in the tightly packed tube and 7·80 inches in the one loosely packed. After the tubes were removed from the vessel the water continued to rise, and in 27 days the water in the tightly packed earth had risen 7·34 inches more, while that in the loosely packed one had only risen an additional 4·21 inches

We know that the capillarity of the soil is favoured by bringing it into a fine porous condition through tillage, and personally I am in favour of tillage done at the right time, but my point is that I think deep tillage is sometimes done too late. Here are problems requiring elucidation.

Cutting out Mother Plants.

What is known as cutting out mother plants is another subject on which there is a diversity of opinion amongst planters. Some hold the view that cutting out the bigger shoots tends to increase the number of canes to the clump by tillering. Other planters look on it as a wasteful procedure, maintaining that after these vigorous shoots have absorbed a quantity of food from the soil it is a mistake to cut them out and give them to the animals to eat. In more than one instance I have observed results where mother plants have been cut out which pointed to the undesirability of this practice. On one estate the attorney and manager, who was a strong advocate for cutting out mother plants, personally directed the labourers employed in cutting out canes attacked by the moth-borer to cut out all mother plants and any extra vigorous shoots which appeared as if they would arrow when the flowering-time arrived. The deputy-manager, who was a disbeliever in the advantages supposed to be derived from cutting out mother plants, only allowed the labourers to cut a portion of the field as directed by the manager, the remainder having only the canes injured by the moth-borer removed. When the canes reached maturity there was a marked difference in favour of those in which the mother plants had not been cut out. On another occasion, the manager of an estate cut out the mother plants of half a field of young canes which were supposed from their mode of growth to be particularly benefitted by this treatment. The clumps had two or three large horse-whip like shoots towering over a limited number of much shorter ones. Here, too, the results were strongly in favour of the non-cut portion of the field.

One year at "Dodds," after cutting out all the canes attacked by the moth-borer in one field, I had, in addition, the mother plants of every alternate four rows cut out. On testing the results we found that where the mother plants were not cut out there were 2,070 canes more per acre—weighing 3·7 tons—than where the

mother plants were cut out. At 12*s*. 6*d*. per ton this would be $11.10 (£2 6*s*. 3*d*.), very nearly twice as much as the average value for five years of an acre of Indian corn in the United States of America.

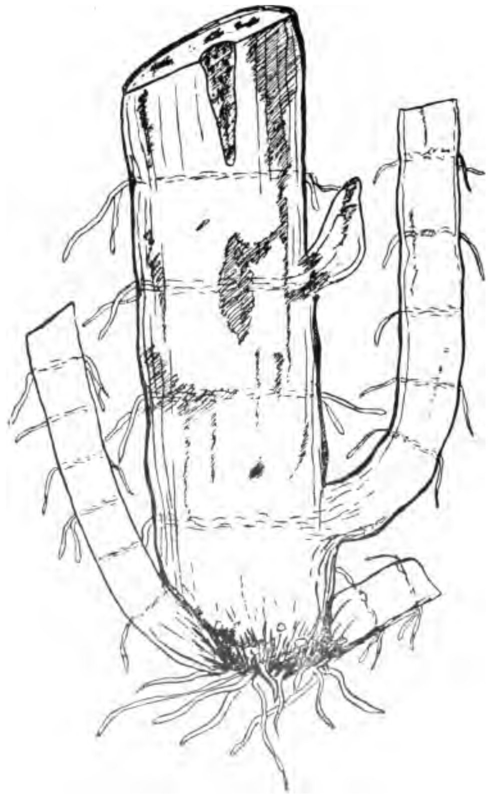

FIG. 32.—Lower end of cut-out "mother-cane." (Diagrammatic.) The large central mother-cane has been cut across at the level of the ground. The shaded patches indicate the discoloured areas. A tunnel of the lady-bird borer is also shown.

To ascertain what happened when a mother plant was removed, I recently cut out nine mother plants in nine different holes of

canes at Dodds. A fortnight after cutting out the first six, I had three of the clumps of canes dug up, and in nearly every case the cut ends of the canes had a fungus growing in them, and beyond the fungus there was a red discolouration of the fibro-vascular bundles extending through the piece of mother-cane and passing into the shoots which had grown from its side buds. (Fig. 32).

In addition to the fungus, four of these remaining pieces of mother plant contained larvæ of the lady-bird borer (*Sphenophorus Sacchari*); one stool had two, one had three, and two one each of these pests. When examining these stools I also carefully looked to see if cutting out the mother plants had caused any new suckers to be formed, and only in two instances had fresh ones started into life since the mother plants had been cut out. Of course, I am fully aware that as "one swallow does not make a summer" so one cannot draw definite conclusions from one agricultural experiment. But, if the data obtained by these experiments are confirmed—which I think rather likely, judging from the results mentioned above—can we, under our present economic conditions, afford to lose what in some other countries would be looked upon as a remunerative return ?

What seems indicated here as the results of my observations and the experiments at Dodds, viz., the undesirability of cutting out mother plants, appears to be confirmed by the results obtained by Dr. Stubbs in Louisiana ; he says, when writing on the number of immature canes obtained in his suckering experiments, "This, with other records, showing conclusively that the buds or eyes on the base of the young sprout will germinate whenever favourable conditions are presented, and are not regulated by age, size of sprout (*i.e.*, mother plant), or soil."

Will not some of you endeavour to solve whether it is desirable or not to cut out what are known as mother plants ?

Choice of Canes for Planting.

Another subject for consideration and experiments is—(*a*) what canes should we plant from, plant-canes or first or second ratoons ? (*b*) what part of the individual cane should we use—top, middle, or butt ? and (*c*) as to the individual canes, should we use large canes, medium size canes, or small canes.

From 1888 to 1893 experiments were conducted at Dodds with the object of supplying an answer to the first question, namely, whether canes should be planted from the tops of plant or ratoon canes? In 1890 the answer was in favour of plant-cane tops by 1·86 tons of canes per acre; in 1891 by 4·39 tons per acre; in 1892 the result was in favour of the tops of first ratoons by ·68 tons; and in 1893, 1·48 tons in favour of the tops of plant-canes.

In Louisiana similar experiments carried on for six years have given results slightly in favour of tops of ratoon canes—Dr. Stubbs' conclusions from the result of the experiments being that good stubble (*i.e.*, ratoon) canes are fully the equal, if not the superior, of plant-cane for seed.

The next question is, what part of the cane is it best to plant—tops, middles, or butts? At Dodds, so far our results have been contradictory. In 1890 the results were, both in the plants and the ratoon experiments, in favour of canes grown from pieces of cane as compared with canes grown from tops. In 1891, owing to the number of plants that failed to grow, the experiment was abandoned. In 1892 the results in a field lined 6′ × 6′ were as follows:—plant-canes, tops 30·27 tons; plant-canes, first cut 21·37 tons; ratoons, tops 30·95 tons; ratoons, first cut 30·95 tons. In a field lined 5′ × 5′ the results were:—plant-canes, tops 28·65 tons; plant-canes, second cut 29·36 tons; ratoons, tops 30·54 tons. Excluding the results of the plant-canes first cut, with which there is evidently something very wrong, the results are practically the same. In 1893 the results were plant-canes, tops 39·23 tons; plant-canes, first cut 35·73 tons; plant-canes, second cut 34·98 tons; plant-canes, third cut 34·46 tons; first ratoons, tops 37·75 tons; first ratoons, first cut 31·73 tons; first ratoons, second cut 33·47 tons. This year the results were in favour of plant-cane tops by 3·5 tons over the first cut, 4·75 over the second cut, and 5·27 tons over the third cut. Plant-cane tops were 1·48 tons over first ratoon tops, which plot was itself higher than either first ratoons, first or second cut.

Taking the experiments as a whole, they are in favour of tops from plants being used for cuttings, and tend to confirm what I heard a successful planter say once, viz., that fields planted with first crop plants gave a quarter of a hogshead of sugar per acre more than if they are planted with second crop plants.

The remaining question is, shall we plant from large, medium, or small canes? To this no answers are forthcoming from Dodds, as

no experiments for clearing up this point have been undertaken, but in Louisiana, Dr. Stubbs has asked the question, and the answer is in favour of planting from large canes. He says, "In 1894 the largest stalks that could be selected from the general crop were used to plant a plot. Stalks of medium size and of the smallest dimensions were also simultaneously selected, and each planted separately in adjoining plots. From these three plots were selected the next year the 'largest' stalks from the 'largest' plot, 'medium' sized stalks from the 'medium' plot, and the 'smallest' canes obtainable from the 'smallest' plot, and each planted again on adjoining plots. This has been repeated six times since, and each planting carried into first and second year stubbles. Thus, fourteen results have been obtained up to date, and the following are the averages :—

"For the large 30·30 tons per acre; for the medium 29·85 tons per acre; for the small 25·95 tons per acre. An examination of these averages will show the diminished yields occasioned by the use of small inferior stalks for seed. This is quite apparent every year in the plant-cane, where decreased tonnage is visible to the eye in either the first or second year's stubble, and is revealed only by the scales.

"The difference between the results from 'large' and 'medium' canes is not strikingly marked, but it is believed that a continuation of these experiments will show here as elsewhere that 'like produces like,' and it will be profitable to plant strong, large, and vigorous canes for seed."

In Java, experience of late has gone to show that, at least with ripe canes, the top shoots of the stem (except the very young shoots) are the strongest and give the most vigorous plants.

Mode of Planting Canes.

Now, as to the mode of planting canes, should they be planted with a drill or hoe? Some advocate one way, some the other, which is the better no one that I know of can definitely say.

Again, some planters take the cuttings after they are cut to the estate yard for the purpose of soaking them for a night in water or in lime and water. Other planters take them directly to the field in which they are to be planted. If the latter plan answers, why

go to the extra expense of soaking them. This is a small matter in itself, but tends to keep up the cost of production, and if we can prove that there is no necessity to soak the cane plants, why do it? There is no doubt, however, that soaking kills some of the insect pests.*

The above are a few agricultural problems in connection with the sugar-cane which await elucidation. On the solution of these and other agricultural problems, together with the erection of Central factories, hangs, I believe, the fate of sugar growers in Barbados. Central factories will aid us considerably, but, with the present outlook, if we are to exist as a sugar-producing country, there is no doubt but that we must reduce the cost of growing canes.

I will now turn to a few problems in connection with some of the intermediate crops, such as sweet potatos, yams, and Indian corn.

Sweet Potatos.

Up to quite recently, so far as I know, only a few experiments have been conducted with sweet potatos.

Some of the questions to which answers are required are :—

1. What variety of the sweet potato gives the best yield, due regard being given to the time taken to mature, and to keeping qualities?

2. What manure is best suited to its requirements?

3. Will it pay to manure sweet potatos, either as an intermediate or rotation crop?

4. Should cuttings for reproduction be taken from vines grown from roots only, or will it suffice if this is done at intervals? If at intervals, how many times can cuttings be taken from vines grown from cuttings without injuriously affecting the yield?

5. When roots are planted for the purpose of providing cuttings, should large or small roots be used?

6. Are any special parts of the vines best for cuttings, that is, should cuttings be taken from the ascending portion of the vines or from the portion that lies on the surface of the ground?

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* In some experiments undertaken last year in Java to test the effectiveness of coating the cut surfaces of cane plants with various antiseptics it was brought out incidentally that soaking plants tended to hasten their growth but that it did not materially increase the total sprouting.

Varieties of sweet potatos.—With regard to the first question, I may say that at present we are now testing twenty-eight different varieties at Waterford under similar conditions. As I am desirous of obtaining all the varieties grown in Barbados, I will read the names of those I have under cultivation, and I shall be glad if anyone who has other varieties will be so good as to give me a few small potatos to plant so that I may in time test their value. The varieties I have are Trinidadans, Johns, White Bourbon, Fill the Pot, Red Sealy, Hurley, Caroline Lee, No. 1 Trinidad, Minuets, No. 4 Trinidad, White Gilkes, which take three months to mature, White Gilkes, which take six months to mature, Fire Brass, No. 2 Trinidad, White Sealy, Vincelonians, Barker, Blue Bird, Joe Mender, Bequia, White Mary, Red Bourbon, Boot Heel, Honey-church, Moffard, Cover the World, Love Drops, and Brass Cannons.

Manuring sweet potatos.—To the second question, what manure is best suited to their requirements, I have no answer at present to give. To the third, I may say that I know of one instance where an application of phosphates and potash—to a field of sweet potatos grown as a rotation crop—gave excellent results. On the estate to which I refer, every other six rows of the potatos had applied to them a mixture of basic slag and sulphate of potash—at the rate of 300 lb. of the former and 150 lb. of the latter per acre. The yield from the unmanured plots was 13 lb. per hole, and from the manured plots 20 lb. per hole. The former sold for 4 cents. and the latter for 6 cents. per hole. The unmanured plots realised $58.08 and the manured plots $87.12 per acre. The difference in favour of the manured plots was $29.04. The cost of the manure was $8.03 per acre, leaving a profit of $21.01 per acre. Assuming the basic slag to contain 40 per cent. tricalcic phosphate and the sulphate of potash 52 per cent., the manured potatos received about 120 lb. tricalcium phosphate and 78 lb. potash per acre.

The weight of sweet potatos per acre from the unmanured portions of the field was 8·42 tons and from the manured 12·96 tons per acre, or an increase of over 53 per cent. In this instance it certainly paid to manure the potatos. To give some idea of what such a profit would be considered in some other countries, I may mention that in the United States of America, taking the average yield of Indian corn there, it would represent the entire revenue from three acres without deducting the cost of production.

Propagation of sweet potatos.—To question four, should cuttings for reproduction be taken from vines grown from cuttings, or should they be taken each time from vines grown from roots, or will it suffice if the vines for reproduction be grown occasionally from roots, I may say that on some estates small potatos are regularly planted for growing vines from which fields of potatos are to be planted later. But in many instances I fear no care whatsoever is taken in this respect, anything in the shape of a potato cutting being considered good enough for planting.

Now, as to the size of the seed potatos, should they be large or small? I once heard a planter say that he planted large seed potatos instead of small ones, and that the yield from the cuttings taken from these large potatos was very much better than that from cuttings grown from small potatos.

With regard to the best part of the vine to be used for cuttings. Some planters hold the view that cuttings taken from the branches that lie along the ground give better results than those taken from the ascending ones. Others, again, hold that it makes no difference but few have, I believe, made any attempt to solve the question.

To judge from what the late Sir Joseph Paxton—a distinguished English horticulturist—says on the subject of growing plants from cuttings, there is probably some difference. "In plants where there are two kinds of branches, one sort ascending and another branching along the ground like runners of strawberries, the difference is much the same as that between common shoots and suckers in ordinary shrubs and trees. The lower trailing shoots, employed for propagation, form plants very like those from suckers, healthy, vigorous and disposed to occupy a large space without blooming. Cuttings of the upper shoots produce flowering laterals in a very short time. Indeed, the dimensions and early blooming of the plant may be regulated by the distance at which the cutting is taken from the main stem. Cuttings from the extremity flower speedily and in a dwarf condition. Cuttings from a shoot in an early stage of its growth will constitute larger specimens, and be longer in bearing flowers."

Mode of planting sweet potatos.—Another matter, too, is, should sweet potatos planted in fields, from which cane plants have been taken at the close of the year just as the dry season is setting in, be

planted in hills or at the corners of the cane holes? So far as I can gather, planters in the middle, south, and east of Barbados generally adopt the first method, while those at the northern extremity often adopt the latter. These are all matters which require investigation, so that we may know which plan is the best.

YAMS.

As far as I can judge, the usual method of planting yams is for a hole to be dug where a clump of canes has recently been cut, that is, in planting parlance, "the old cane hole is opened," a basket of light manure or fine, half-rotted megass, &c., placed therein, a hill or bed formed thereon, and a piece of yam planted. In due time a cane hole is dug between the hills and farmyard manure placed in it. Now, it seems to me that this usual method is not the one likely to be most successful if a good crop of yams is desired. If a growing yam is carefully dug up without injuring the roots, it will be found that the roots are mainly at the junction of the stem with the tuber. From which it would appear that for the best results to be obtained the manure should be placed around the hill, on the surface, or just under it. An old planter once pointed out to me the mistake generally made, and told me how he first knew it. He said two peasant proprietors, who lived near where he did, were in the habit of planting yams. One man took great pains with the preparation of his land, but applied the manure in the manner first described. The other man took much less pains, but he placed his manure on the surface of the hills. Observing that the latter almost always obtained a good return, he asked him if he could account for his return being better than his neighbour's. His reply was that his neighbour put the manure where the yam roots could not get it, he put his where they could. To give another instance in proof of the desirability of placing the manure upon the hills or yam beds Talking some weeks ago on the subject of growing yams to a scientific gentleman who owns an estate and takes a keen interest in agricultural matters, he told me that he never grew good yam crops until he had a growing yam dug up and studied the root formation. Since then, by putting the manure where the yam roots can benefit by it, he has obtained much better results.

Indian Corn.

As a rule the crops of Indian corn in Barbados are miserably small, rarely exceeding ten bushels per acre. Exceptions, however, are occasionally found like the yield at Hill View plantation in St. John, where the corn some two years ago, on being measured, was found to be thirty-one bushels per acre.

One is not surprised at the small yields usually obtained, considering the little care or attention the crop gets, and one often hears the remark that it does not pay to grow corn as the yield is so small. This remark is, I believe, often made without due consideration, and, as was first pointed out to me by Mr. T. B. Evelyn, Junior, of Gibbon's plantation in Christ Church, a mistaken one. Take by way of example the yield of a ten acre field of Indian corn grown as a catch crop. The yield of this field would be, say, 100 bushels worth, at 80 cents. per bushel, $80. With two yoke of oxen, a small plough, and a man and a boy the field can be prepared at a cost of 80 cents ; planting the corn would cost $1.20, supplying, singling, and moulding up the corn would cost about $2.50, reaping $2.50, drying and storing, say, another $2.50, making a total of $9.50, or, to be on the safe side, put the expenditure at $12. No account has been taken of the weeding, as whether the corn was grown or not, if the field is being prepared for canes it will have to be kept clean.

In this case the corn would cost, say, 12 cents per bushel. If fed to the stock, it would save buying American corn, which is now $2 per bag of 110 lb. or $1 per bushel.

The day is not far distant when planters will, I believe, have to attend to these small economies on the estates if they are to survive as sugar planters. In the past it was no doubt economically right to buy cheap American corn and oats with dear sugar, but now with the present price of sugar I maintain it is a wrong policy and one which tends to keep up the cost of growing our staple crop.

LECTURE VI.

THE INSECT PESTS OF SUGAR-CANE AND ASSOCIATED CROPS.

BY H. MAXWELL-LEFROY, B.A., F.E.S.,

Late Entomologist to the Imperial Department of Agriculture for the West Indies.

The subject of this lecture is "The Insect Pests of Sugar-Cane and Associated Crops," a subject of considerable importance to all engaged in agriculture in this island.

Insects may be studied from many points of view, but one group only is of interest to planters, namely, the insects that are injurious to crops and the best remedies that may be adopted to check them. Before discussing remedies it is necessary to know what insects attack the crops, and to learn their habits and methods of attack. It is then possible to see how they may most easily be destroyed, or, at least, how any injury arising from their presence may be prevented.

There are three points to be considered in formulating remedies : the remedy must be effective, it must be so simple as to be easily applicable under the ordinary conditions of estate work, and it must cost little ; that is, it must aim at effectiveness, simplicity, and small cost. There are many methods of destroying insects, all of which are not applicable under the conditions of estate work or labour that apply here ; those which can be carried out must cost little or the saving effected by destroying the pest and preserving the crop is swallowed up in doing so.

Having secured a remedy that is effective, simple, and not too costly, there remains but to put it in practice, and this is the part remaining for those actually engaged in agriculture. Few people will probably deliberately prefer to suffer loss from insect attack if they can be assured that this loss can, by simple means, be prevented. The following pages are intended to show how the losses now sustained in Barbados from insect attacks may be averted by the adoption of remedies that are effective and simple, and whose cost is but a fraction of the amount annually lost through insect pests.

Compared with the neighbouring Colonies, Barbados appears to have but few pests. It is convenient to deal first with those of sugar-cane, then with those of sweet potato, corn, and other crops, and to close with some general observations.

MOTH-BORER.

The most serious pest of sugar-cane is the moth-borer (*Diatræa saccharalis*, Fabr.). It is impossible to examine canes in any stage of growth, or to inspect the ripe canes in the estate yards during the crop season without seeing the very evident damage caused by this insect.

Planters are so accustomed to it that probably the damage is rarely estimated at its full worth. What would be the increase of yield if moth-borer were exterminated? Any increase of yield is very desirable indeed, and, whilst on some estates it would amount to between 15 and 20 per cent., on the average, judging from careful observations of the canes in the last two seasons, it should be between 5 and 10 per cent. It is not necessary to enlarge on this point; a careful examination of the canes now growing in the fields would be the best argument in favour of the adoption of remedies. It is important to emphasize the fact of the damage which is in many cases allowed to continue unchecked from year to year.

Admitting that moth-borer is a pest, what measures can be adopted against it? The life history (see *West Indian Bulletin*, vol. i., p. 329) of this pest may be here passed over. A careful study of local conditions and this year's experience has shown that there are two remedies which stand above all others in effectiveness, simplicity, and small cost: these are collecting the eggs and cutting out the attacked shoots (dead hearts) in the young canes. Many

other remedies have been discussed, and the full particulars of these may be found in the *West Indian Bulletin*, vol. i., p. 338, but none are so well adapted to the conditions obtaining in Barbados.

Collecting the eggs is a simple operation that can be carried out by a gang of children. Anyone who knows the appearance of the eggs on the leaves can teach such children their work in half an hour. Once taught they need only the supervision of an old man or woman, and can do the work thoroughly well.

Egg-collecting is best done at the close of the crop season, for at that time the old canes no longer offer a shelter to the moths, which must lay all their eggs on the young canes where they can be easily collected. The gang must be large enough to collect the eggs on every acre of canes once a week, and this must be done thoroughly for six weeks on end at least. In practice it is found that one child can do about nine acres a week, and the number of the gang may be calculated accordingly.

There is no doubt as to the effectiveness of this remedy since it destroys the insect before it can do any damage. Its simplicity is also certain; not only has the work done by these gangs been carefully tested, but they have been taught in half an hour how to do the work. The fact that on one estate over 100,000 egg-clusters were collected this season also speaks for itself.

Finally its cost. This table gives the cost of collecting eggs on 100 acres of canes for one season :—

11 children for six weeks at 8 cents per day	...	$31.68
1 woman " " 20 " "	...	$ 7.20
		$38.88

or roughly $40.

This is the cost of applying this remedy over 100 acres for one season; it will need but a small increase of yield to pay for this method of treatment.

There is one point that needs to be carefully borne in mind when collecting eggs. The eggs should not be destroyed at once, as this will also destroy the parasites (*Trichogramma pretiosa*, Riley, and *Telenomus* n. sp.) which are often found destroying a portion of the eggs. The collected eggs should be placed in an open box and exposed to the sun, when the sound eggs will be

killed, but the parasites will be uninjured and will emerge from the eggs to continue their useful work. In this way the numbers of the parasite are not checked, nor do any caterpillars hatch from the sound eggs.

Cutting out dead hearts.—This remedy, which dates back some years, is familiar to all, and it is only necessary to point out the importance of cutting out the attacked shoot low enough to be certain of removing the caterpillar or chrysalis of the moth-borer. This remedy should be applied for at least twelve weeks, commencing early in the life of the cane. Every acre of young canes should be examined regularly once a fortnight. It is estimated that one man will cut out the dead hearts and cover the cut stumps with mould on ten acres of young canes per week. The cost, then, for 100 acres will be :—

Five men for twelve weeks at 20 cents per day, $72. Against this cost may be set the value for fodder of the shoots cut out, which will vary according to the number of dead hearts found per acre.

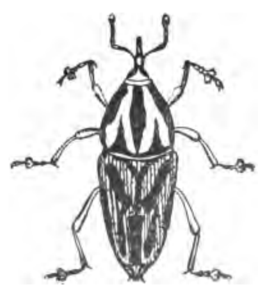
It is now possible to consider whether it is desirable to adopt these two remedies. Probably none can be found which are so directly effective ; they are so simple as to be easily carried out by the estate labourers, and the cost of the two amounts to $112 per 100 acres. It would certainly be possible to carry these out regularly on every estate at least for two seasons until the effect could be seen and their value proved.

The matter may be put in another way. Insect pests may be regarded as insect life in the wrong place, just as it is reasonable to look on weeds as plant life in what is, for planters, the wrong place. The two, insect pests and weeds, are in this respect strictly comparable. The planters of Barbados pride themselves justly on the freedom of their fields from weeds, and from inquiries made as to the amount spent yearly in weeding cane fields it is found that a reasonable estimate is 2½ to 3 dollars per acre, that is, from $250 to $300 per 100 acres. It is as important and as useful to spend $112 per 100 acres on destroying the chief insect pest as it is to spend $250 to $300 on destroying weeds. This insect pest may claim almost as much importance to the cane as the weeds, and every estate should, as a matter of course, deal with moth-borers as regularly as it does with weeds. There is no apparent reason why Barbados should not pride itself on its freedom from

moth-borer just as it does on its freedom from weeds, at a much less cost, and with a materially increased yield from its canes as well.

Weevil Borer.

The pest of next importance is the ladybird or weevil borer (*Sphenophorus sericeus*, Oliv.), an insect familiar to all here (Fig. 33). As this pest has not been dealt with before, its life history may be described in detail.



x2.

Fig. 33.—Weevil borer (twice natural size).

The egg is a small white oval object, $\frac{1}{15}$th. inch long, laid by the female in the cane itself. It may be found embedded at a depth of $\frac{1}{6}$th. inch below the surface (Fig. 34). In four days it hatches, a small white grub which immediately commences to eat the tissue of the cane. As it feeds it makes a small tunnel, and continues eating straight into the cane. Growth is slow at first, the grub barely doubling in length in ten days, but in five weeks it has attained about half its full size. It eats continuously, making large tunnels as it becomes full grown (Fig. 35), doing a very great amount of destruction. When it is full fed it makes a cocoon (Fig. 36) of the long fibres of the cane, and transforms to the chrysalis. It remains as a chrysalis for some time, finally emerging from the cocoon as the perfect insect, which escapes from the cane and flies away. The life history occupies about two months from

the time the egg is laid till the perfect beetle emerges from the cane, but there is a considerable variation in the periods occupied by the grub and the chrysalis stages.

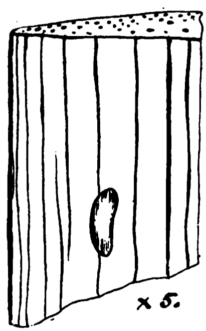


FIG. 34.—Egg of the weevil borer embedded in the cane (magnified five times).

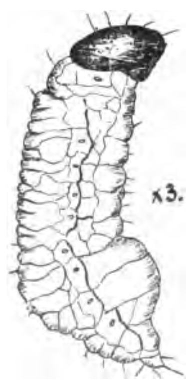


FIG. 35.—Grub of the weevil borer, from the side (magnified three times).

The eggs are laid in the cut or broken surface of the cane, the female being unable to pierce the hard rind of the older joints. The eggs may also be laid in the upper joints of the cane where

the rind is softer. Each egg is laid singly, and the female continues producing and laying eggs for many days.

This insect is destructive in a variety of ways. A large proportion of the canes found to be rotten at crop time have been eaten by this insect, and as these canes are entirely useless, the greater number appear to be left in the field when the canes are cut, and so are not found in the estate yards. It is not certain whether any large proportion of canes so attacked have been broken or injured in the field, thus admitting the beetle. It is probable that in very many cases the attack has commenced in the sound cane, the beetle laying eggs in the softer upper part of the growing canes. If this

FIG. 36.—Cocoon of the weevil borer (natural size).

is so, the insect is responsible for the destruction of a large number of canes and becomes a very serious pest. Many more canes may be found to be injured by this insect than should have been broken or wounded in the field during growth, and so many canes are destroyed by this insect that it will, at least, be advisable to take measures to check it.

In addition to the attack on growing canes, this insect may be found in the stumps of ratoon canes, in the stumps of canes cut for plants, and in the plant canes in the ground. In fact, wherever the cut surface of a cane is exposed, the female insect lays eggs. This has been tested in many ways, and it is found by experiment that the mere exposure of a cut cane in the field for a few days is sufficient to attract the beetles, which lay their eggs in the cut surface.

It is not certain whether the presence of the grubs in the ratoon stumps leads to weakness in the shoots which spring from those canes ; but there can be no doubt that plant canes so attacked are weakened and spring badly. A plant cane in the ground may be attacked in four days from the time of planting, and the whole interior having been eaten out, the young shoots are less vigorous and grow badly.

Stated shortly, this insect is injurious to the cane in four ways : it attacks any cane which is cut, broken, or wounded during growth ; it can attack growing canes at the soft upper joints ; it is found in ratoon stumps and plant-canes.

Knowing its life-history and methods of attack, it is possible to consider how best to combat it. It is not possible to prevent its entrance into canes that are broken or wounded in the field ; the only precaution is to break or wound as few as possible. Neither can the attack on the soft upper joints be prevented. The injury to ratoon stumps can be avoided by lightly covering them with mould as soon as possible after the canes are cut. The injury to plant-canes can only be arrested by covering them with mould when they are planted. In addition, every precaution should be taken to check its increase, and this is probably the most effective method of procedure.

Remedies.—Little has been written about this insect in the past, so that any recommendations may be looked on as new and therefore untried. But the following simple remedies are at least worthy of careful consideration, and, if they can be applied, will probably do much to check the increase of this pest.

(i.) *Destroy all rotten canes at crop-time.*—This has been urged before for other cane pests, and is of great importance for this insect. Canes containing the weevil borer in all stages can be found in probably every estate yard during crop-time, and if these canes, which are useless for making sugar, are not ground or burnt at once, the insects pass through their transformations and come out. In addition, there are usually many rotten canes which are left in the field ; these should be collected, and ground or burnt as soon as possible.

The destruction of these canes is a source of loss, and this fact alone has probably prevented its being done before. Equally it is inconvenient to grind them during crop season ; but the increase

of moth-borer and ladybird borer are so materially assisted by not grinding or destroying these canes that every effort should be made to do so.

(ii.) *Cover ratoon stumps lightly with mould as soon as possible after the canes are cut.*—This is of great importance, and might be done when the stumps are cleared of trash immediately after the canes are cut. If this is not done, the stumps become acid and attract the beetles which lay their eggs in the cut ends. If broken pieces of cane are placed in any cane field, large numbers of beetles will come as soon as the canes become sour. It is an infallible method of obtaining these beetles, and the ratoon stumps act in just the same way if they are left exposed. The longest interval that should elapse between the cutting of the canes and the moulding is four days.

(iii.) *Destroy stumps not intended to be ratooned within six weeks of cutting.*—This is also of importance as the beetle breeds abundantly in these stumps. Of a cartload of stumps of canes which had been cut for planting in December of last year, not one could be found which did not contain the grubs of this beetle. Had these stumps been left in the ground or even dug and kept, very large numbers of beetles would have come out. The same is found in the stumps of canes cut at crop-time. By destroying these stumps within six weeks, large numbers of the insects will be killed before they can complete their transformation and come out, and one of this beetle's chief breeding places will be removed.

(iv.) *Cover plant canes with mould or plant deeper.*—I put this forward with some hesitation in view of Mr. Bovell's remarks in the last lecture. If the plant will spring equally well when lightly moulded over, it will be well to do so and so save these canes from attack by the ladybird borer.

These remedies may be summed up thus :—

(1.) Destroy as many of the insects as possible in the rotten canes.

(2.) Prevent as far as possible its breeding in the ratoon stumps and plant canes.

(3.) Destroy its other breeding places, namely, stumps not intended to be grown.

The remedies proposed above are simple in that they involve no new estate work ; they consist only in changes in the present estate practice. There are many other ways in which this insect may be destroyed, as, for instance, by the use of lights, by trapping them in little heaps of sour canes, by leaving pieces of sour cane in the fields for the females to lay eggs in, &c. But these involve special labour, and the insect can probably be checked by the four remedies suggested above. It remains to be seen whether these suggestions are practical ; and in view of the importance of this insect, and the fact that it is apparently not checked by any parasite or special enemy, it is very desirable that an attempt should be made to check its numbers.

Root-Borer.

The next pest for consideration is the insect described as the "root-borer." Very little is known about this insect as yet. During December and January of last season five cases were found of nearly mature canes withering up completely. Patches of ten to fifty holes of canes would dry up and die for no apparent reason, and on examination it was found that in each stool the part of the cane below the ground had been extensively bored and destroyed by the grubs of a beetle (Fig. 37). The grubs ate into the under-

FIG. 37.—Grub of the root-borer, from the side (magnified twice).

ground base of the cane from below and destroyed the tissues ; in consequence water was unable to pass up into the cane from the roots and the canes withered. No other explanation was forthcoming in any one of these cases, and I do not hesitate in attributing the damage to this insect.

Attempts were made to keep such stools in boxes and rear the perfect insect, but during my absence from the island they all died and the perfect insect has not been obtained. The grub is distinct from the grub of the ladybird weevil both in habits and structure, and is apparently the grub of a weevil similar to that insect. It differs markedly from the very common grub of the hardback beetle (*Ligyrus tumulosus*, Burm.) (Fig. 38), which never bores into

FIG. 38.—Grub of the "hardback," from the side (magnified three times).

the cane and should not be confused with it. Little attention has been paid to the "root-borer," but such cases of the withering of canes are not uncommon, being ascribed to other causes. Every case of injury that may appear to be due to this insect should be investigated, and if planters will assist in this matter, it will be possible to obtain fuller information.

The insect may prove to be abundant and widespread, or may be of rare occurrence, but in view of the serious damage it can cause, we should know all about it. The only remedy possible under the present conditions is to dig the stumps, burn them, and fork in a heavy dressing of lime or artificial manure to kill any of the insects that may remain in the ground.

CANE FLY.

Another pest of less importance is the "cane-fly" (*Delphax saccharivora*, Westw.). Planters are familiar with it as the cause of

the "black blight" on canes. Fortunately it seems to occur but rarely. It is a small flying insect (Fig. 39) which sucks the juice of the leaves of the cane ; its eggs are laid in the cane blade covered

FIG. 39.—Cane-fly (much magnified).

with a little tuft of white cottony wax. The insects excrete a sweet liquid which falls on the leaves of the cane and enables a mould, the black blight, to make its appearance. Black blight is a sign of the presence of the cane-fly, and is itself of little importance. No case of the cane fly has been found serious enough to warrant the adoption of remedies. Its natural enemies are so numerous that they appear to be able to keep it in check as a rule. A useful way of checking the increase of the insect consists in collecting its eggs on the young canes when the eggs of the moth borer are collected. The little tufts of white cottony wax are readily seen and collected, and with little additional labour the excessive increase of this insect may thus be averted.

CANE MEALY-BUGS.

Other pests of sugar-cane are of minor importance. I may mention the mealy-bugs (*Dactylopius sacchari*, Ckll. and *Dactylopius Calceolariae*, Mask.), soft mealy pinkish insects covered with wax, which live under the leaf sheaths and suck the juice of the cane. These are common pests which rarely injure the canes. When very abundant, the cane loses vigour and remains small owing to the excessive loss of juice. Canes which naturally drop their trash do not appear to suffer from these insects, which only live under the leaf-sheaths.

Careful selection of plant canes so as to get only those which are free from mealy-bugs is the very simple and effective method of checking them. When plant-canes are cut from infested plants, the pest is naturally transmitted from crop to crop ; but if care is taken to select clean plants, the insects could not easily attack the young crop as they can move but little, and only the newly-hatched young ones are able to migrate from stool to stool.

There are numerous other insects which live on the canes in various stages of their growth. These may be passed over as they are not of sufficient importance to rank as pests, though they might increase and become troublesome in the future. The list of real pests includes only the moth-borer, the weevil-borer, the root-borer, the cane-fly, and the cane mealy-bug.

Compared with other crops, this is a small list of pests, and it consists of insects which may all be easily dealt with. A united effort on the part of all the planters of this island would soon render these practically harmless ; failing that, there need be no appreciable loss on any estate if these remedies are applied within the limits of that estate ; and the insect pests that attack the cane are as much within the control of planters as weeds are, at a much less expenditure of labour and money.

Sweet Potato Pests.

In dealing with the pests of sweet potato the three serious ones only will be mentioned, namely, the "potato moth," the "blight," or red spider, and the "scarabee" or potato weevil.

Potato Moth.

The potato moth (*Protoparce cingulata*, Fabr.) (Fig. 40) is the insect known locally as the "Harry Booby." The female moth lays eggs on the leaves of the sweet potato, and these hatch to small caterpillars. The caterpillar (Fig. 41) feeds on the leaves, eating most voraciously and rapidly increasing in size. The appearance of a field is very striking when hordes of these insects have appeared and are eating it steadily down, leaving behind them nothing but bare stalks. When the caterpillar has eaten all it wishes it descends to the ground and transforms there to the

chrysalis. It remains as a chrysalis (Fig. 42) for about eleven days and then the moth emerges. After mating the female lays eggs and the pest reappears.

As a rule potato vines eaten once only do not suffer unless the weather is very dry. Should rain fall the vines spring again and the crop is retarded but not injured. Serious loss may follow if a second or third attack succeed the first ; the moths that emerge

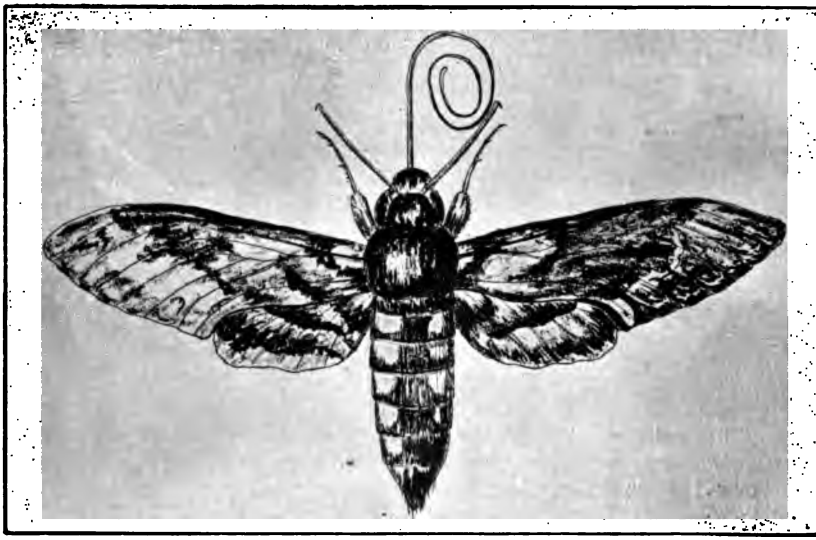


FIG. 40.—The sweet potato moth (natural size).

from the first attack may lay eggs on the same spot, and the caterpillars will then be found again about three weeks after the first attack. This may occur a third time, when the vines are unable to recover and no potatos are formed.

In every case of a second attack on the same field it would be advisable to immediately take steps to destroy the caterpillars. This may be easily done by the use of arsenical poisons. The vines

are sprayed with a mixture of arsenical poison, lime and water ; there are several such poisons, of which the best, perhaps, is "Paris Green." This is used at the rate of 1 lb. of Paris Green, 2 lbs. of lime, and 200 gallons of water. Any spraying machine may be used, but one

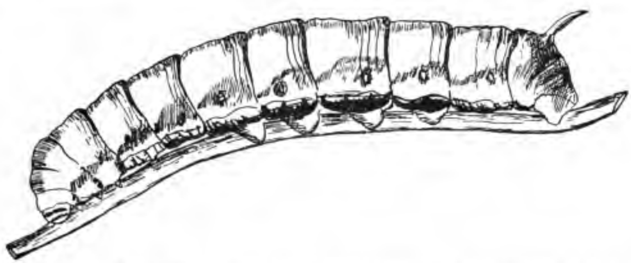


FIG. 41.—Caterpillar of the sweet potato moth (about natural size).

of the best is a Knapsack Machine which a man can carry strapped on his shoulders. With two men to carry the machine alternately, one working the machine the other holding the nozzle, about two acres can be done daily with one knapsack sprayer. The effect of

FIG. 42.—Chrysalis of the sweet potato moth (about natural size).

the spraying is to poison the leaves; the caterpillars eat the leaves and are speedily killed. There is no doubt of the effectiveness of this treatment, its application is easy and the cost is small.

The cost works out thus, per acre :—

2 men for half a day	20 cents
*2 women "	10 cents
$\frac{3}{5}$ lb. Paris Green	30 cents
	60 cents

* The women are required to carry water to supply the machine.

This is the cost of treating one acre of sweet potatos once at the local price of material and labour. In view of the value of this crop, this remedy is worth applying whenever the yield is likely to be diminished. The average profit from one acre of sweet potatos may probably be taken at \$24, so that this treatment costs only $2\frac{1}{2}$ per cent. of the normal returns.

The only obstacle in the way of the adoption of spraying is that there are not a sufficient number of the necessary machines in this island. A spraying machine costs in New York \$11, and there should be no difficulty in procuring a supply of, say, one dozen for the use of planters, so that any outbreak may be immediately dealt with. The poison can be applied in a simpler manner by dusting it on the vines when they are wet with dew or rain, but this is likely to be less uniformly carried out and will cost more for labour. If the necessary machines were here, it would be better to use them. Failing these, the pest may be checked by carefully dusting the poison over the vines from cloth bags.

BLIGHT.

The second pest of sweet potato is the blight or red spider (*Tetranychus telarius*, Linn.). This is not an insect but a near ally of the true spiders, and its minute size renders it difficult of observation.

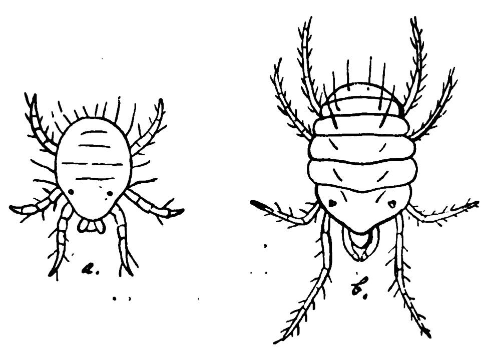


FIG. 43.—Red spider—(*a*) the young; (*b*) the full grown (much magnified and head downwards).

Sweet potatos attacked by this pest are easily recognised : the leaves curl up, turn yellow and drop off. The vines wither and the plants do not form large tubers. The red spider may be found in enormous numbers on these leaves, and it will spread from one spot, slowly extending over a whole field. There are two simple remedies for this pest, spraying with kerosene emulsion and dusting with lime and sulphur. Spraying with kerosene emulsion is similar to spraying with Paris Green, with the substitution of the emulsion for the Paris Green.

The cost works out thus, per acre :—

2 men half a day	20
2 women half a day	10
120 gallons kerosene emulsion	$3.45
	$3.75

Dusting with lime and sulphur is simpler and equally effective though more costly. It consists in applying lime and sulphur to the plants, dusting it over by hand.

The amounts used are :—

Flowers of sulphur 1 oz. } per cane hole.
Lime ... ... 4 oz. }

With 1,742 cane-holes per acre, the cost is :—

Lime, 435 lb., at 7 cents per bushel	$ 40
Sulphur, 109 lb., at 10 cents per pound ...	$10.90
Cost of application	$ 24
	$11.54

In both of these cases the success of the treatment depends on immediate application as soon as an area is seen to be badly affected. Planters would perhaps hesitate to spend so much on every acre, but it will be worth while doing so for a small patch where the attack is commencing. This disease does not break out simultaneously over a whole field, but commences at one spot and spreads. If that spot is at once treated, the disease is checked, and the expenditure of a few dollars will save a large field.

Potato Weevil.

The remaining pest of sweet potato is the potato weevil or "Scarabee." The tubers of the potato are attacked by a small beetle* (Fig. 44) which lays its eggs on the outside of the potato

Fig. 44.—Sweet potato weevil (magnified four times).

whilst in the ground. The grubs (Fig. 45) that hatch from these eggs eat their way into the potato, making a narrow tunnel. Owing to this the potato acquires a distinct odour and becomes unfit for

Fig. 45.—Grub of the sweet potato weevil (magnified four times).

food. When the grub is full grown it changes to the chrysalis (Fig. 46), and after five days it emerges as the perfect insect.

Fig. 46.—Chrysalis of the sweet potato weevil (magnified four times).

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* A weevil as yet undetermined. It differs from the potato weevil of Jamaica (*Cylas formicarius*).

The periods taken are :—

	Days.
Egg	5
Larva	20
Chrysalis	5
Total	30

The attack of this insect is not noticeable until the crop is nearly ripe, which, in bad cases of attack, will be partially or entirely lost. Once the crop is attacked no remedy is likely to be of any avail. Preventive measures are all that can be adopted, and these are at present very little known. The only measures that can be definitely recommended are the destruction of badly infested crops, and the cultivation of other crops on infested fields for at least a year after.

The destruction of the attacked crop is all important. Very large numbers of these insects are found in each tuber. From one medium sized tuber, freshly dug, 721 were extracted in all stages of growth. The insects continue increasing in the potatos till all are consumed, and if such a crop is left in the ground, enormous numbers of the insects will be produced and will infest neighbouring fields. The destruction of such a crop is not easy, but the tubers might possibly be buried in a pit under at least 18 inches of hard packed soil or boiled in a tayche full of water or crushed. There is, in addition, the expense of digging the worthless crop, but if this pest is ever to be checked, the potatos must be dug and the insects in them destroyed by some means. No experiments have been possible up to the present, but it is hoped that the most economical method of destroying the insects in such tubers may be found by experiment. One other measure may be suggested on which experiments could usefully be made. In fields where an attack is expected a heavy dressing of artificial manure could be applied when the plants are half-grown. Whether a sufficiently heavy dressing could be applied to keep off the insects and not injure the plants can only be determined by experiment, and no opportunity has yet been found for such an experiment.

Of the three pests of sweet potato this is perhaps the most serious ; it is also the most difficult to deal with, and it becomes of great importance to check the increase by the regular destruction of

infested crops. In addition, care must be taken not to replant infested fields with potatos for as long a period as possible.

Indian Corn Pests.

The insect pests of Indian corn next deserve attention. I am aware of two only, the corn "ear worm" and the corn "stalk borer."

The Corn Ear Worm is a caterpillar that eats the young ears and the leaves. It hatches from eggs laid on the plant, and subsequently transforms to a small moth. The damage to the ear is of less importance than the damage to the leaves, as in the latter case the plant becomes weak and does not produce large ears. The treatment at present adopted of dropping ashes or mould into the plant is probably sufficient to deal with the first form of attack, but this might be improved by the use of lime instead of mould, and by adding some Paris Green to the lime or ashes used.

For the attack on the leaves spraying with Paris Green should be adopted ; the cost would not exceed 60 cents per acre, as for sweet potatos, and estimating the profit from this crop at $7, it will pay to save the crop by spending 60 cents per acre.

The Corn Stalk Borer is the moth-borer of cane, and any remedies against this insect in cane will probably be sufficient to prevent any loss in corn. In bad cases the eggs of the moth-borer can be collected on the leaves of the corn ; and this will be the most satisfactory method of dealing with it.

In addition to the pests that attack Indian corn in the field there are insects which damage the corn after it is stored. In the pamphlet on *General Treatment of Insect Pests*, p. 23, issued some months ago, the following paragraph may be found :—"Stored crops are very liable to the attacks of insects. Grain may be freed from weevils by exposing it for 24 hours in an air-tight receptacle to the fumes of carbon bisulphide at the rate of one teaspoonful (one drachm) per cubic foot of space. This will kill every insect within 24 hours and will not damage the grain. Carbon bisulphide is obtainable in cans from 7 lbs. upwards at about 5*d*. per lb. in England or the United States. Benzene may be used in the same way, taking rather more per cubic foot as it is less powerful. As both these substances are very inflammable, care must be exercised in

using them." This treatment is very simple and practical, costing but little. Carbon bisulphide is obtainable here, and one pound, costing locally 55 cents, is sufficient for 240 cubic feet of corn, or a ton of grain.

The corn is exposed to the fumes of the liquid in a closed box or bin for 24 hours. It is then stored in a place that has also been fumigated just beforehand. Corn for seed is treated in the same way, and after the vapour has gone from the seed it may be sealed up in a tin or box till it is required.

The only pest remaining is the insect that has this year eaten the green-dressings so abundantly. This is the caterpillar of a small brown moth, which is found in enormous numbers eating the leaves of woolly pyrol and other green-dressings. The simple remedy for this is to spray the plants with Paris Green or other arsenical poison. This treatment is identical with that for other caterpillar pests and will be found fully effective if adopted in time.

General Summary of Remedies.

The chief insect enemies of sugar-cane and other crops have now been dealt with and the most suitable remedies enumerated. The number of injurious insects is comparatively small ; perhaps there are others that are of equal importance which have not been prominent during the past two years.

Of those discussed above, some have been fully worked out, whilst we lack information regarding others. Such information can only be obtained by the co-operation of the planters with the Department, and it is to be hoped that in the course of the next year many gaps in our knowledge may be filled, notably with regard to the ladybird borer, the root-borer, and the potato weevil. For every pest more or less simple remedies have been proposed, capable of application here at any time.

The remedies may be summed up thus :—

Collecting eggs of moth-borer.
Cutting out deadhearts.
Destroying diseased canes.
Covering ratoon stumps and plant-canes with mould.
Destroying stumps not intended to be ratooned.
Spraying with arsenic or kerosene emulsion.

Application of lime and sulphur.
Destruction of "scarabee" potatos.
The use of carbon bisulphide.

With the exception of spraying all of these are remedies applicable without further appliances or skilled labour on any estate in this island. In the case of spraying, this is a useful remedy for potato moth, potato blight, corn worm, and green-dressing worms, so that there is scope for the use of the machines. A spraying machine is as much an agricultural tool as a hoe or a plough, and if it were so regarded its use would be far more general. The working of the machine is simple, it is not likely to get out of order, and it is very effective. Treatment could be adopted for these pests if a supply of these machines were kept here for the use of planters, and it would be of advantage to all to be able to deal effectively with sudden outbreaks of these pests.

The above methods of destroying insects are in reality part of the regular routine work of the estate. They are at present not familiar to everyone in Barbados, but pests will certainly always be here and will destroy varying amounts of the crops until remedies are adopted—not as extraordinary things, but as part of the natural work, just as ploughing, hoeing, or forking are regularly undertaken.

As the year commences and the plant canes come up, signs of the moth-borer are looked out for and presently the regular gang of men is set to cutting out deadhearts and doing the necessary work in the young canes. During crop season all the diseased canes are carefully collected and either passed through the mill at regular intervals or immediately burnt. The stumps of the ratoon canes are lightly moulded over immediately after the canes have been reaped, and within six weeks of cutting all the stumps not to be ratooned are dug and burnt. The regular gang of children are collecting eggs during the closing weeks of crop season, and the canes then grow up free from moth-borer and ladybird weevil. Wherever sweet potatos are grown a watch is kept for signs of the blight or of scarabee, and should the potato moth appear, the spraying machine is called into use. The corn worm may be found ravaging part of a field, and here, again, spraying is at once undertaken. At the close of the year planting comes round and the plant-canes are carefully selected free from disease and are planted with the upper end covered with mould. This finishes the insect

work for the year, with the exception of any incidental pests that need treatment, and the round commences again. This is roughly the sort of work that should be done on every estate. It does not call for any difficult work nor for great expense, and the results would very soon be manifest. Probably no pests are easier to deal with on the whole than these, and it is to be hoped that the time is not far distant when they will be dealt with in some such way as has been described.

Perfect results will only be obtained by the co-operation and concerted action of all, and this is peculiarly important in the case of such pests as potato moth or potato weevil which can spread from place to place. A single attack of potato moth left unchecked may be the cause of widespread attack soon after, the moths that emerge in one place spreading perhaps over the whole island. If every case of potato moth were at once dealt with there never could be a case of a second or third attack following in the same field ; and the failure to stamp out such a pest as soon as it appears not only exposes the first attacked field to a second or third attack, but also lays the whole island open to attack.

In the case of other insects such as moth-borer or potato blight, the pest is less likely to spread or spreads far more slowly, and so the lack of effort on the part of one planter only slowly affects his neighbours. I wish to guard against misapprehension on this point; for most pests each will lose much or little according to his individual efforts ; an estate that is kept free of moth-borer, for instance, does every year become slightly infested from neighbouring estates, but this occurs to a very slight extent, and it is not a wise policy to do nothing oneself because one's neighbours equally are doing nothing.

The Origin of Insect Pests.

It is not unreasonable to wonder how it is that there are such things as pests, that any insects should be able to increase and be so destructively abundant. This condition is due to a variety of causes—too many and too complex to enter into at great length—but it may be possible to give a rough picture of what was the probable sequence of events.

Some centuries ago the vegetation of Barbados was wholly wild ; there was no cultivation, and wild plants grew all over the island.

Just as the vegetation was wild and, so to speak, mixed up, so the animal life was wild, and the insects and other creatures were such as could find food among these plants and live under these conditions. Some insects, for instance, fed on these wild plants, others lived in the soil or among the roots, others, again, bored into the trees, whilst many ate other insects or were parasitic on them. Under natural conditions it is rarely that any insect becomes too abundant, the whole of the life, both plant and animal being, as it were, balanced, and we may suppose that this was so at that time also.

When man came and began to cultivate the ground he first destroyed the native plants here and there. The insects that lived on those plants must then either die or find other food, and the original balance of life was at once upset. Then man planted crops, such as cane, sweet potato, corn, &c. He did not plant them as they grow in nature, a plant here and another there, but he grew them in large areas, so many acres of each in one locality. The insects that could not find their natural food then either died or fed on these crops. Any insect that could live on the cane, for instance, would find it in abundance ; it had not to search about for fresh food as it did under natural conditions, but it found a large field and was able to live easily and also increase enormously. The potato moth also would not have to fly about seeking for plants on which to lay its eggs. It found ample plants in one spot and so was not exposed to dangers from birds, lizards, &c.

Upsetting the balance of life would also disturb the birds and insects that destroyed others ; in nature there were parasites which check other insects just as there are now, and the altered conditions would affect them too.

The consequence would be that insects that were formerly checked would now increase enormously, such insects as could live on the crops becoming very abundant. Since that time the whole island has been cultivated, and the insects we have now are either those which could still live wild under the changed conditions, as, for instance, many beetles and butterflies, or such as live on our crops or on other insects. There is a new balance of life established, but this is unfavourable to man, for his methods of agriculture favour destructive insects and also continually tend to disturb the existing balance. In the first place, man plants continuous areas of each crop ; this offers a very evident advantage to the pests. Then

he plants the same crop repeatedly. In nature if an insect eats all its food plants, the next generation is largely destroyed by the want of food and only a few survive. But now man plants the same crop repeatedly and the pest always finds food and is not checked as it would be in nature. Then, again, man does not plant the same relative amount of each crop every season ; sometimes the absence of a particular crop is beneficial to man by checking its pests, but equally in other cases the undue preponderance of another crop is an encouragement to its pests and so is damaging to man. Also the variation in the relative amounts of each crop continually disturbs the balance of life and reacts again in many complex ways on the animal and plant life.

Man, again, introduces new plants and cultivates them. This is a disturbing factor. He also introduces new pests, perhaps with the new plants, perhaps by the medium of ordinary commerce, and these new pests do not here have the checks they had in their former locality. Having no parasites at first, they can become very abundant, and it is often a long time before any natural check is formed. Thus, most of the scale insects that are destructive in this island are certainly introduced from other localities.

Man also introduces new animals, such as birds, mammals, &c. The mungoose is such a case ; it was introduced into the West Indies some years ago and is said to have eaten the ground-feeding birds, the lizards, and the frogs, and so has destroyed many animals that eat insects. In Barbados, the effects of the mungoose are less evident than elsewhere because the chief insect eater, the blackbird (*Quiscalus crassirostris*) is independent of the mungoose and still abundant. In Antigua, under similar conditions of climate and crops, where there is no blackbird, insect pests reach a far greater pitch than they do here, and this is with good reason attributed to the mungoose. Montserrat, on the other hand, has no mungoose and the ground lizards are very abundant, doing the work of the Barbados blackbird.

This is an instance of how the introduction of a new animal has disturbed the whole balance of life, and there are other instances of less prominence. Having in different ways done this, the crops grown by man suffer from the excessive increase of insects that feed on them. In many cases a new balance of life is established, and were nothing to disturb that, the natural checks such as birds, climate, and parasites might keep most of the insects within certain

limits ; but these limits are not always so narrow as man would wish. A pest may be so limited by natural causes that it can only destroy a proportion of its food-plant, but that proportion may be large enough to be of great importance to man, as happens in the case of moth-borer in sugar-cane.

We have seen that man establishes a new balance of life, perhaps unfavourable to himself, between plants, insects that destroy those plants, and animals that destroy those insects, but that this balance tends to be continually disturbed by a variety of causes. In addition to this, the natural variation in the increase of an insect is sufficient to enable it to become periodically abundant. The usual checks on insects are absence of food-plants, climatic conditions and enemies. Let us suppose that there is always an abundant supply of a food-plant, that the climatic conditions are favourable, and that an insect pest of that plant and its parasites are both present. The parasites destroy a certain proportion of the pest, increasing in number whilst they do so. The pest also increases in number but not so rapidly as does the parasite. The parasite becoming increasingly numerous is able to kill off all of its prey except a few scattered here and there. The next generation of the parasite, finding almost nothing to prey on, are themselves killed, leaving a few scattered insects on the food plant. Now the pest, relieved temporarily of its enemy and perhaps favoured by circumstances, suddenly increases. We now see an outbreak of that pest which spreads over the whole area of its food-plant ; the parasite in turn can now find food everywhere and abundance of it, and it sets to work to diminish the numbers of the pest till the parasite in turn becomes abundant. So the struggle continues, and were the other conditions uniform throughout, we should have some such periodic variation as the above. But the conditions are not uniform and favour one or other as may be seen yearly in the relations between moth-borer and its egg-parasite (*West Indian Bulletin*, vol. i., p. 346). I have tried to picture the varying relations of a pest and a parasite as throwing a light on the sudden rise of an insect pest. If we think of the continual struggle going on, each insect striving to increase as fast as its food supply allows it, against the influence of climate, birds, lizards, predaceous and parasitic insects, and its other enemies and dangers, we can dimly see how man by his artificial methods has, and does daily, upset the whole delicately balanced arrangement. The result is that where in nature there would be no undue preponderance of any insect,

there is a perpetual change—many insects suddenly become abundant and destroy the crops. These are our pests, produced by the artificial conditions of our methods of agriculture. The pests having thus been produced there is but one thing to be done, and that is to be prepared to deal with a pest as soon as it becomes destructive. We should always be ready to apply our artificial checks to the undue increase of any insect and so prevent loss. It is now easy to see the significance, not only of insectivorous birds and other animals, but also of artificial remedies.

Man influences insect life very powerfully through bird life, and can often do this favourably for himself. For many years attempts have been made in foreign countries to so favour the increase and spread of insectivorous birds that they would check the injurious

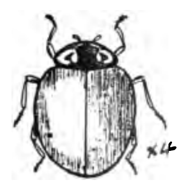

FIG. 47.—Ladybird beetle (*Cycloneda sanguinea*) (magnified four times).

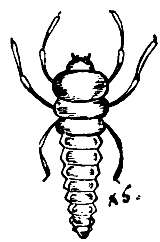

FIG. 48.—Grub of ladybird beetle (magnified five times).

FIG. 49.—Chrysalis of ladybird beetle, as seen on a leaf (magnified four times).

insects without further action on the part of man. This is, perhaps, not wholly possible, but a certain amount can be done towards it. We can at least aid the increase of our useful birds in every way, and not only birds but lizards, frogs, and all pest-destroying creatures. In Barbados there is the blackbird, probably almost entirely an insect-eater, which may constantly be seen eating caterpillars and other insects. The smaller birds are less numerous, but many are probably partly insectivorous. Lizards are useful insect-eaters, and the ground lizard is probably especially valuable ; this seems to have been almost exterminated and is now scarce. The big frog (*Bufo agua*) is also fond of caterpillars, even eating so big a thing as the large potato caterpillar. There are also large numbers

of predaceous and parasitic insects, some of which are of general occurrence. The ladybird beetles eat the blights that are found on many plants and on young cane, corn, ochro, &c. Both the grub (Fig. 48) and the perfect insect (Fig. 47) do this, and they are generally sufficient to destroy all the plant lice on badly infested plants in a short time.

Another useful insect is the lacewing fly (*Chrysopa* sp.); both the grub (Fig. 51) and the perfect insect (Fig. 50) eat small insects, especially the cane-fly; an attack of cane-fly last year that looked

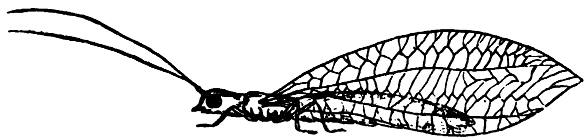

FIG. 50.—Lacewing fly (much magnified).

very serious was checked by the great increase of these insects. There are other useful insects, but they are not always easily recognizable. In a general way all the bees and wasps are useful,

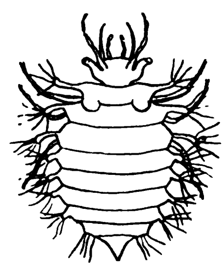

FIG. 51.—Grub of the lacewing fly (magnified).

especially those which live parasitically in or on other insects. Some of the flies are useful, notably the large dark grey fly (*Sturmia distincta*, Wied.) that destroys the chrysalis of the potato moth (Fig. 52).

We have seen that by encouraging the enemies of our destructive insects we may do something towards putting the balance of life in a favourable condition for our own crops. Were this sufficient nothing more need be done, and artificial remedies would be unnecessary. But we see daily that we must ourselves complete the destruction of the pests, and by whatever simple means we can find we must prevent our insect enemies from causing us loss. We should recognise that under our artificial conditions the use of artificial remedies is absolutely necessary if we are to reap the full amount of the crops we grow. Not only are these measures necessary, but they are easy to carry out, and the saving effected is far greater than the money we spend. The money spent on destroying our insect pests is, so to speak, very well invested and

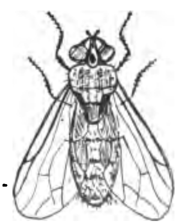

FIG. 52.—Fly (*Sturmia distincta*) parasitic on the chrysalis of the sweet potato moth (magnified four times).

will bring in very great returns. This being so, it is evidently valuable, and simply a matter of common sense, to adopt some remedies even if it is only with a view to the actual saving of that one crop. But the checks we put artificially on the insect pests react also on the future ; not only do we save the present crop, but we are doing work that may be of permanent benefit. The condition of Barbados, as far as its pests are concerned, would not be what it is now if in the past the insects had been dealt with. Also the conditions will be better five years hence for what we now do. If remedies were now generally applied against moth-borer, every year would see less of it until the necessary remedies would involve a very slight amount of labour. No one can predict to what extent the ladybird borer may injure the canes ten years hence, and the

failure to deal with insect pests each and individually, and to take what steps we can to discourage their increase generally, may have very grave effects in the future.

There is but a limited number of insect pests in the island ; the remedies recommended are not difficult to apply and will all bear examination and thorough trial. It is to be hoped that this work may not pass unheeded, but may bear fruit in the immediate future. If the remedies are at least given a fair trial, their use may become more general ; and we may perhaps see the time come when the failure to deal with insect pests is regarded as equally a sign of a bad planter as is the failure to deal with weeds.

Much of the practical work in finding remedies has been due to the co-operation of planters, who have lent their crops or made trials of remedies under the direction of the Department. There may be further pests which have not come under my notice ; and it is to be hoped that planters will not hesitate to assist this work by sending specimens or furnishing information about any insect that may attack any crop. Obviously this work cannot be carried on without the co-operation of planters, and the fact that this work is undertaken primarily in their interests should secure at least a thorough consideration and trial of the remedies recommended for these insect pests

LECTURE VII.

THE FUNGOID DISEASES OF THE SUGAR-CANE.

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The subject of this lecture is "The Fungoid Diseases of the Sugar-cane." Before discussing these diseases and the possible remedial and preventive measures which are practicable on a large scale, it will be well at the outset to give some idea of what fungoid disease in plants really is. Although a perfect definition of disease is somewhat difficult to frame, nevertheless, for present purposes, we can regard disease as a condition in the plant brought about by any interference with the vital processes which make up its life. In the following an attempt will be made to show how fungi are able to bring about a condition of disease in the cane, but before doing this we must have some idea of what is going on in the sugar-cane in health. In other words, we must pay some attention to the physiology of the cane (that is, the normal processes which go on therein) before we can deal with the pathological (*pathos*, disease, *logos*, discourse) side which deals with abnormal or diseased conditions. The reader is referred for details of the anatomy and physiology of the cane to Lecture I. of this series.

Some general considerations of the group of plants known as the fungi may be of interest at this point as they have an important

bearing on what follows. Looking at the vegetable kingdom as a whole we find that it falls into two great divisions—the flowering and the flowerless plants. The members of the former group are characterised by the facts that they bear flowers and grow from seeds; they form the more evident portion of the flora of the land portion of the globe. The flowerless plants do not bear flowers and seeds but grow from small reproductive bodies known as spores (*spora*, a seed) which indirectly serve the same purpose as the seeds of flowering plants. These spores are often so minute that they are easily distributed by the wind. The ferns—which are so characteristic a feature of the flora of the gullies of Barbados and other West Indian islands—mosses, liverworts, sea-weeds, fresh-water algae, fungi and bacteria are the main groups of the flowerless plants. The fungi are thus a group of the flowerless plants and grow from spores. They differ from the rest of the plant world however in one very important respect; they are often white, sometimes brightly coloured, but in every case entirely devoid of the green colouring matter (leaf-green or chlorophyll) which is so striking a characteristic of the vegetable kingdom as a whole. As a consequence they cannot utilise the energy of sunlight to manuacture their food for themselves as green plants do, but are driven to obtain their nourishment in the form of complex organic matter which has already been built up from simple substances by green plants. Those fungi which obtain their nourishment from dead organic matter are known as saprophytes (*sapros*, rotten, *phuton*, a plant), while those which live entirely on living plants or animals are known as parasites (*parasitos*, one who lives at another's expense). Between these extremes there is a very large group—which becomes greater as investigation proceeds—the members of which are partly parasitic and partly saprophytic according to conditions. To this intermediate class, which includes forms exhibiting every gradation between those which are complete parasites and those which are entirely saprophytes, the fungus causing the common rind disease of the sugar-cane belongs. This fungus can behave both as a parasite and as a saprophyte. While a few of the fungi are comparatively large, for instance, mushrooms, toad-stools, and the bracket-shaped bodies seen on old wood, the majority of the group are so minute that they can only be studied under the microscope. This is probably the reason why so little is generally known with regard to them, and especially to the diseases to which they give rise. Formerly the diseases of field and garden

crops which were caused by fungi were regarded with a certain amount of superstitious awe, but during the last forty years the causes of many of these diseases have been ascertained. Still more recent work—especially that carried out on the Continent of Europe with regard to grape diseases, and in the United States on many diseases of fruit trees—has shown how the ravages of many of these troublesome pests can be checked and in some cases wholly prevented.

It is found that the sugar-cane in the West Indies is attacked by several different kinds of fungi and that there are definite diseases of the roots, stem, leaf-sheath, and leaves—as well as of the cuttings used in planting. The whole of these diseases have not yet been worked out and much remains to be done to place the study of the fungoid diseases of the cane in the West Indies on a thoroughly satisfactory footing. We will first of all consider the diseases of cane cuttings and then pass on to the principal root, stem, leaf-sheath, and leaf diseases.

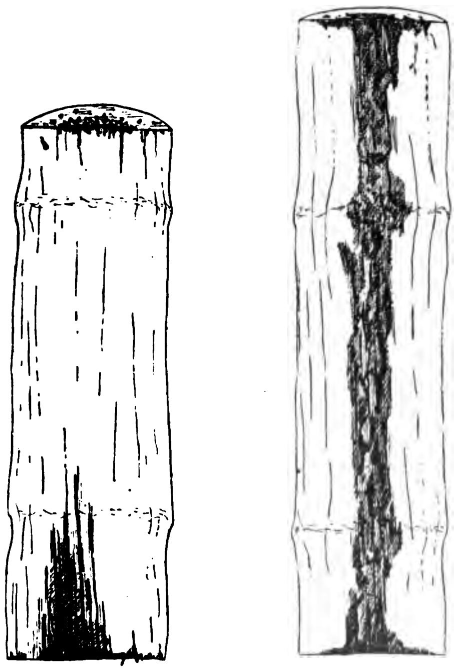
Diseases of Cane Cuttings.

It has been found that the majority of cane cuttings which either do not spring at all or else die out shortly after the young shoots appear above the ground are destroyed by fungi, and especially by a small "mould" which is described below. When these dead cuttings are split open, it is generally found that the central portions are blackened and that the tissues give out a very pleasant smell not unlike that of a ripe pine-apple. Consequently this disease of cane cuttings has been called the "Pine-apple" disease. Two cane cuttings, split open, showing (*a*) the early and (*b*) the later stages of the disease are shown in Fig. 53.

It will not be out of place to trace briefly the life-history of the fungus (*Thielaviopsis ethaceticus*, Went) causing the "Pine-apple" disease of cane cuttings as an example of those which attack the cane.

The blackening of affected cane cuttings (Fig. 53) is due to the formation of large numbers of spores on the part of the fungus by which it is enabled to spread. Some of these spores, highly magnified, are shown in Fig. 54.

When these spores are blown or fall on the cut end of a cane cutting or on a wound of the cane or one of the old leaf bases, they germinate by sending out a minute colourless tube or hypha (*huphe*, a web) which soon begins to branch and give rise to a



a *b*

Fig. 53.—Two cuttings, split in half, showing an early (*a*) and late stage (*b*) of the "Pine-apple" disease caused by the fungus *Thielaviopsis ethaceticus* Went.

complex network of these tubes, a mycelium (*mukes*, a mushroom), which are able to penetrate the tissues of the cutting in all directions. Some of the early stages in the germination of one of these spores are shown in Fig. 55.

In a few days after these spores have fallen upon the end of a cutting the fungus will have grown to such an extent that all the cells of the cutting will have been invaded by the fungus, and its

FIG. 54.—Spores of the fungus *Thielaviopsis ethaceticus,* Went. Highly magnified.

growing power destroyed. In Fig 56 the fungus is represented in the cells of a cutting where it will be seen that it is enabled to make its way through minute openings (pits) in the walls of the cells.

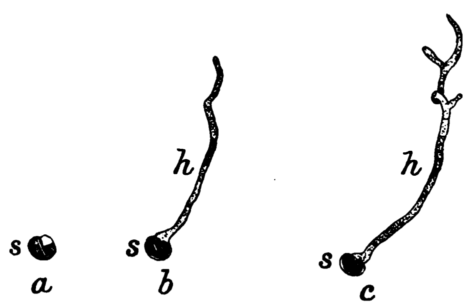


FIG. 55.—Stages in the germination of a spore of *Thielaviopsis ethaceticus*: (*a*) germination beginning; (*b*) germination more advanced; (*c*) hypha beginning to branch; *s*—spore, *h*—hypha. Highly magnified.

When the whole of the cutting has been traversed and destroyed by the fungus and the ground as it were exhausted, the fungus proceeds to form spores exactly like those from which it grew. In

this process, which is represented in Fig. 57, the whole of the material in the fungus is used up and new growth only takes place when the spores are able to come in contact with suitable food such as another cane cutting. Such in brief outline is the life-history of the most important fungus which attacks cane cuttings. To its ravages most of the cuttings which die out and have to be replaced owe their destruction. It is important to bear in mind that this fungus is quite common on rotten canes and on the waste cane which accumulates at planting time when cuttings are being

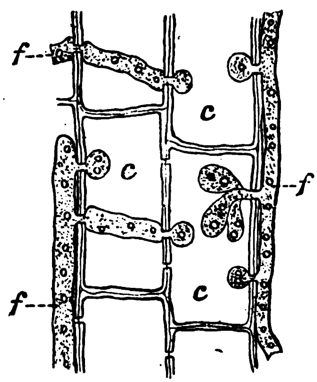


FIG. 56.—A thin slice of an infected cutting showing the fungus in the cells; *f*—fungus, *c*—cell. Highly magnified.

prepared. The fungus also attacks and destroys cane cuttings during transit to other colonies or between different parts of the same colony.

Remedies.—The obvious direct remedy for this disease is to protect the cuttings in such a way as to prevent the fungus gaining access to the tissues. Since the fungus can enter at the leaf-bases and at bruises in addition to the cut ends, it is evident that treating the ends is not sufficient. It has been found that the best remedy is to dip the cuttings in Bordeaux mixture and then to coat the cut ends with tar, when the cuttings are practically fungus-proof. At the same time their growing power is uninjured. It is

essential that the cuttings be passed through Bordeaux mixture *as soon as they are prepared*, otherwise there is great danger of the fungus invading them. The tar can be applied best when the ends of the cuttings are dry. It should be rendered more liquid by the

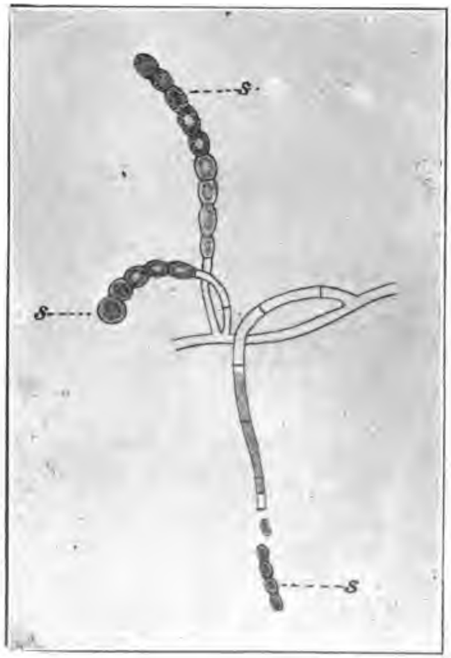


FIG. 57.—Formation of spores (*s*) by the fungus *Thielaviopsis ethaceticus*, Went. It will be seen that these are formed in chains. Highly magnified.

addition of half a pint of methylated spirit or kerosene oil to each gallon of tar. Directions as to the preparation of Bordeaux mixture are given in the *West Indian Bulletin*, Vol. II., p 210. Dipping the cuttings in Bordeaux mixture alone is a fairly efficient remedy, but is not so safe as the double treatment. Not only should cuttings which are to be planted immediately be treated as above, but also those which are sent to various parts of the Colony or exported to

other parts of the West Indies. It has been found that the growing power of treated cuttings when kept fourteen days is almost double that of untreated cuttings which have been stored the same length of time.

Another remedy, which is of an indirect character, is to destroy the sources from which the cuttings are infected. These are undoubtedly the heaps of rotten canes which are sometimes allowed to accumulate, and the waste cane left over when the cuttings are prepared. The rotten canes should be destroyed and the waste cane disposed of as soon as possible. When practicable, cuttings should be prepared and treated in the field to be planted rather than in the estate yard. The advantages of this procedure would be a smaller danger of the cuttings being infected and also less damage to the buds in handling.

Cost.—The cost of the treatment of cane cuttings recommended above is very small and works out as follows :—

Fifty gallons of Bordeaux mixture will treat 25,000 cuttings—sufficient for 20 acres—and this costs 72 cents.

	$
Six pounds of copper sulphate (blue stone) at 10 cents a pound	.60
Four pounds of unslaked lime	.04
Labour	.08
Total	$0.72

One gallon of tar at ten cents will coat the ends of 6,000 cuttings—sufficient for five acres. The cost of the tar per acre is therefore two cents.

Four boys at eight cents a day will treat 6,000 cuttings in a day with Bordeaux mixture and tar. The cost of labour per acre is therefore six cents.

The cost of the treatment per acre with Bordeaux mixture and tar is therefore—

	$
Bordeaux mixture	.04
Tar	.02
Labour	.06
Total	$0.12

For Bordeaux mixture alone the cost is—

	$
Bordeaux mixture	**.04**
Labour	**.02**
Total	**$0.06**

Thus the cost works out at 12 dollars per 100 acres for the double treatment and six dollars per 100 acres for Bordeaux mixture alone. These estimates refer to fields where 1,200 cuttings to the acre are planted.

Root Diseases.

Several root diseases occur in the West Indies which, to a casual observer, are apparently identical as far as the above-ground manifestations go. The reason for this uniformity of aspect in cane-stools attacked by different root diseases will be evident from what follows. It will be remembered that the roots of the cane are provided near their growing ends with numerous structures known as root-hairs which are pieces of living machinery by means of which alone water and mineral substances are taken by the plant from the soil. These root-hairs contain living protoplasm which can only work properly when supplied with oxygen. Thus, unless the spaces between the soil particles contain air the root-hairs stop work and the plant in consequence suffers. Hence it follows that cane roots can only develop healthily and work normally in properly drained soil in which the mechanical condition is suitable. In the following diagram (Fig. 58) two root-hairs, *h* and h^1, are represented among the soil particles in an ideal soil.

When the air spaces between the soil particles are replaced by water or where they do not occur in sufficient size and sufficient numbers—as in a soil which has not been properly drained and cultivated—the normal working of the root-hairs is interfered with and a condition of things arises in which the destruction of such roots by fungi speedily follows. It will thus be evident that a proper condition of the soil, both as regards drainage and mechanical condition, is of the first importance in helping the sugar-cane to withstand root diseases.

The fungi which attack the roots of the cane cause damage in the following ways. In some cases the roots are attacked just as they are springing from the parent cane and their growing points destroyed. Such roots are therefore incapable of further development and cannot be of any use to the plant. In other cases the filaments of fungi gain access to the central water and mineral conducting vessels of the roots and interfere with the upward passage of these essential materials to the leaves. Further, the growing

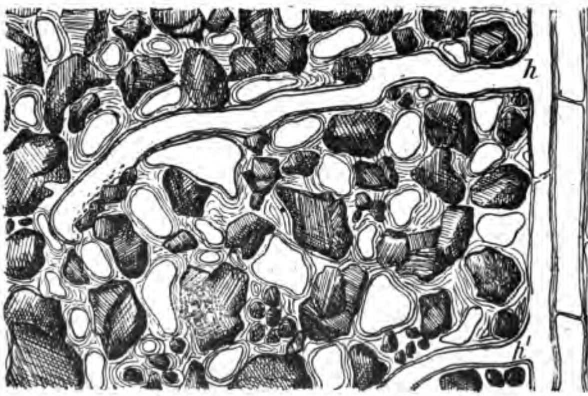


FIG. 58.—An ideal representation of two root-hairs of a plant among the soil particles; *h* and *h*[1] are the two root-hairs, one of which is represented adhering to the soil particles at the free end. The soil particles are heavily shaded, the water films represented by concentric lines, and the air spaces are indicated by the clear areas. After *Sachs.*

ends of the cane roots are sometimes attacked and the root-hair region destroyed. We can regard these root-destroying fungi as enemies attacking the cane at its base of operations and causing damage by interfering with the absorption and transport of water and mineral substances from the soil to the leaves. Thus it will be evident that no matter what fungi are concerned in the process, the effect on the plant will be much the same, namely, a stunted and dwarfed habit with a tendency to throw up numerous shoots from the lower buds which do not, however, form healthy stems as they

are in turn attacked by the same fungi which have affected the parent canes. Such cane stools are regarded as being attacked by "Root fungus" which we can regard as a useful term covering several apparently distinct diseases, the precise nature of which is now being investigated.

It is very probable that the principal fungus attacking the roots of the cane in the West Indies is a small toadstool—apparently a species of *Marasmius*—which is to be seen after rain in great

FIG. 59.—Portion of the lower part of a young cane shoot from a stool attacked by root disease. The toadstool fungus *Marasmius* is shown in various stages; (*a*) a portion of the underside of the cap of the toadstool slightly magnified.

numbers on the lower parts of the canes attacked by root disease. A portion of a young cane shoot from a diseased stool on which these toadstools are developed is shown in Fig. 59.

Canes attacked by this fungus are further characterised by the fact that the old leaf sheaths are cemented to the stem of the cane by means of a white, musty-smelling growth which is composed

largely of a matted mass of the filaments of the fungus. As is to be expected ratoons are much more liable to the attack of root diseases than plant-canes. In the former case the condition of the soil cannot be so favourable to healthy root development as in the first crop, consequently the fungi attacking the cane roots cause a greater amount of damage in the case of ratoons than in plant-canes.

Remedies.—The remedies that can be taken in the case of root diseases which are, in Barbados, responsible for more loss than any other diseases of the cane are as follows :—

1. In the case of badly attacked fields the land should be thrown out of cane cultivation as long as possible and other non-gramineous plants cultivated. All trash and old cane stumps should be destroyed by burning, the land ploughed up, and on no account should pen manure be applied to such a field until it is replanted with canes. In this way the fungus is starved out and disappears.

2. In cases where the disease is noted in a healthy field the diseased area should be surrounded by a trench a foot deep, and care should be taken to throw the soil dug out of the trench on to the diseased area. As these fungi travel underground the diseased area can be isolated in this way. A similar isolation should be practised when a whole field is attacked so as to cut it off from the rest of the estate.

3. The trash from badly attacked fields should be burnt and on no account used for mulching young canes. Indeed, the greatest care should be taken in selecting the trash used for mulching only from healthy fields.

4. On estates where root disease occurs the greatest care should be taken in the selection of cuttings. In no case should these be obtained from canes on which the trash adheres to the stem, and the lower two feet of the cane should never be used for cuttings. All cuttings should be placed in Bordeaux mixture for at least six hours and then tarred at the cut surfaces.

Stem Diseases.

Although there are several different fungi which attack the stem to the cane, the fungus which causes the common "rind disease" is

by far the most destructive. It will not be out of place therefore to give an account of this disease and the remedies which are applicable to it. The disease generally makes its appearance among the canes in Barbados about the month of November, after which it becomes much more common as the canes become ripe. The first symptom

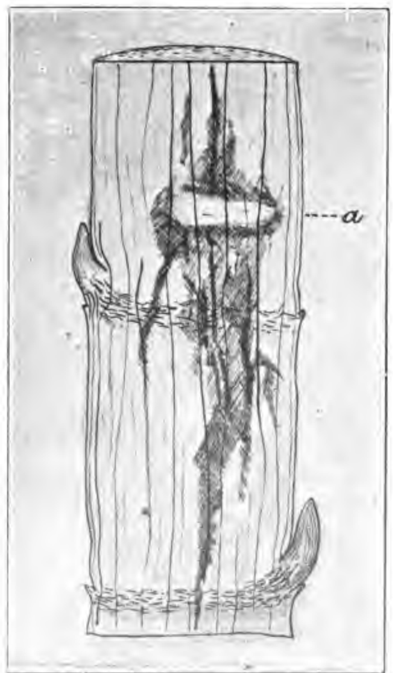


FIG. 60.—A portion of a cane attacked by the rind disease split in half. The shaded portions represent the red blotches in the centre of which white areas (a) can be seen.

of the disease is the gradual drying up of the leaves at the upper part of the cane. The outer leaves dry up first and the withering commences at the edges and tip of the leaves and gradually spreads inwards. The drying spreads to the younger leaves until the whole

of the tuft of leaves is brown, the process taking from four to six weeks. If a cane is examined in which the drying up of the leaves is only just beginning, no external symptoms of disease will be noticed until the cane is split in half down the centre when one or more of the internodes (joints) will be seen to be coloured reddish. The red colour is not uniform. Here and there darker blotches will be seen in the centre of each of which a definite white area will be apparent. These white areas are usually shaped like an ellipse, the longer diameter stretching across the cane. The appearance of such a diseased portion of a cane split in half is shown in Fig. 60.

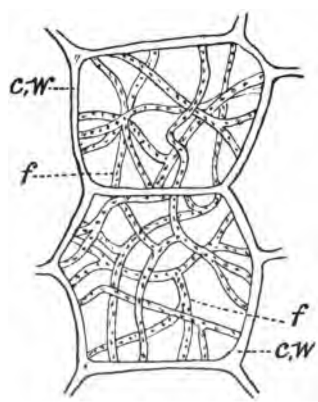


FIG. 61.—Two cells of a cane shown in cross section taken from a portion attacked by the rind disease. The filaments of the fungus contain rows of oil drops which are represented by dark dots; *f*—fungus, *c.w.*—cell-wall. Highly magnified. After *Went.*

On examining thin slices of the discoloured tissue a fungus can be seen in the cells which is very characteristic in appearance. The filaments of this fungus are filled with rows of oil drops and are represented in Fig. 61.

By the time the whole of the bunch of leaves of the diseased cane is dried up, the rind shows very distinct evidences of disease from the outside. The diseased portions are brown in colour and show a certain amount of shrivelling. On careful examination of these

discoloured areas the fruits of two fungi will be observed. The one which is most abundant and most evident is formed under the rind as small black dots which burst through as a long slender, dark, hair-like filament. This form is not the cause of the disease and does not attack healthy canes. It only infects canes which are previously diseased. The second fungus has been found to be the

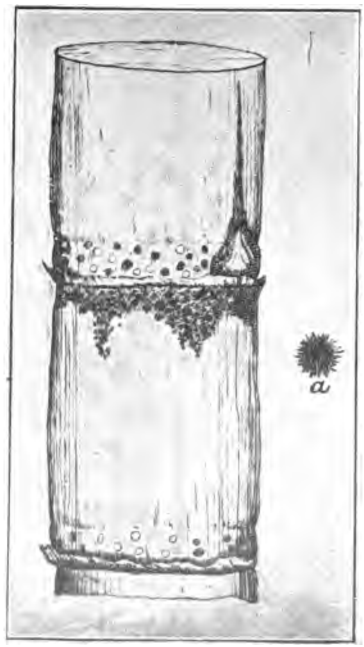


FIG. 62.—A portion of a diseased cane showing the fruits of the fungus causing the rind disease. These appear as dots above and below the leaf-base. At (*a*) one of these fruits is shown on a larger scale.

cause of the rind disease. Curiously enough it is not so abundant on the diseased canes as the fungus which produces the dark hairs, and in the earlier studies of this disease was overlooked. The fruits of this fungus are to be seen, on careful examination with a lens, on the discoloured areas as a rule just below the leaf base at

the node or else among the sleeping roots at the beginning of the internode. They appear as minute black velvety circular patches and are shown in Fig. 62.

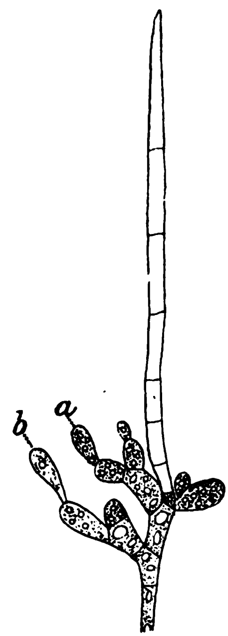


FIG. 63.—A hair from a spore colony of the fungus causing the rind disease showing how the spores (*a*) (*b*) are formed near the base. Highly magnified. After *Went*.

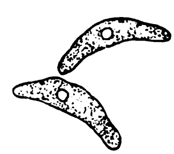


FIG. 64.—Mature spores of the fungus causing the rind disease. Highly magnified. After *Went*.

The velvety appearance of the fruits of the fungus is due to the formation of dark hair-like bodies at the base of which the crescent-shaped spores of the fungus are formed. One of these hairs and the formation of spores near the base is shown in Fig. 63. Some of the mature spores themselves are shown in Fig. 64.

This fungus is very common on "rotten canes," and also occurs on dead cane leaves in fields attacked by the rind disease. It has been proved that if these spores are placed in the tunnels of the moth borer or weevil borer, on a wounded surface or even at old leaf bases, that the disease will attack and destroy the cane. A disease identical with the rind disease of the West Indies occurs in Java where it is known as "Red Smut," and also in other countries where the cane is cultivated.

We can regard the fungi of the cane stem as enemies which invade the tissues of the stem and thus attack the lines of communication between the soil and the leaves, and also as enemies which destroy the reserve store of cane-sugar in the stem. As the filaments of these fungi live partly on the sugar in the cells of the cane, the juice of such attacked canes is always poor and often worthless.

Remedies.—The most suitable remedies with regard to the rind disease of the sugar-cane are as follows :—

1. The destruction by burning of all rotten canes and of trash from diseased fields, since both of these contain the spores of the fungus which gives rise to the disease. If rotten canes are left about the estate yard, the next crop of canes will become diseased, and if trash from diseased fields is used to mulch young canes, these will in time become affected. Rotten canes may either be destroyed by passing through the mill and burning the megass in the ordinary way or else by the Java method of piling them in heaps, pouring kerosene oil on them and setting fire to the heap. Perhaps the best way of destroying the trash from diseased fields would be to set fire to the field where this can be done with safety.

2. The borers which attack the cane should be kept in check since the fungus can easily enter the canes at the borer holes. This matter is dealt with in the previous lecture.

3. In fields where the disease has commenced to show itself the portion of the field affected should be reaped at once so as to save as much sugar as possible and to prevent the disease spreading. This measure is important on account of the low purity of the juice of badly diseased canes, and the rapidity with which the disease spreads.

Diseases of the Leaf-sheath.

Several different fungi, of which the one described below is the commonest, attack the leaf-sheaths of the sugar-cane. The damage done by these leaf-sheath fungi is not so great as that caused by the fungi which attack the cuttings, roots, and stem of the cane. We can regard these parasites as enemies on the lines of communication between the stem and the leaves; they interfere both with the passage of water and minerals to the leaf and also with the passage, in the reverse direction, of manufactured sugars from the leaf to the stem.

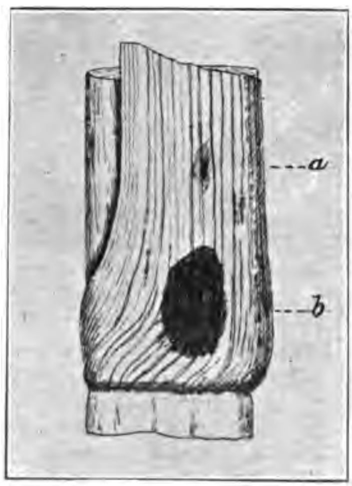


Fig. 65.—A portion of the upper part of a cane showing a leaf-sheath attacked by *Cercospora vaginae*, Krüger. (*a*) An early stage of the disease; (*b*) a later stage where the spores are being produced. After *Wakker*.

The commonest of these leaf-sheath fungi is a dark coloured mould fungus (*Cercospora vaginae*, Krüger) which produces a reddish discolouration on the leaf-sheaths in which at a later period an oval black patch appears. At this central dark portion, the spores of the fungus are produced. The appearance of a diseased leaf-sheath is shown in Fig. 65.

The fungus spreads very rapidly from the older to the younger leaf-sheaths as can be readily seen on stripping off the leaves of an attacked cane.

Remedy.—The only remedy that would appear to be practicable would be to strip the canes several times during their growth. This would probably both check the fungus, diminish the risk of cane fires, and also tend to improve the quality of the juice and hasten the ripening of the canes. In addition, the canes would be washed and cleaned by the rain and the danger of infection by the fungus producing the rind disease would be diminished, since the canes would dry more quickly after rain than when unstripped, and thus there would be less chance of the spores of the fungus germinating and entering the cane. The planters might find it worth their while to strip half of their fields and compare the difference in the cane juice and yield of sugar with the cost of stripping. In Java canes are stripped several times and the trash is carried out of the fields and burnt.

Leaf Diseases.

There are several fungi which attack the leaves of the cane in the West Indies and cause yellowish marks to appear thereon. Except where the damage is very great these leaf diseases are not of such importance as those described above. They damage the cane by destroying a certain amount of the green surface of the leaf and thus interfering with the important processes which go on therein.

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